# ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. LVI. No. 16. 220 Broadway, New York, October 18, 1906.


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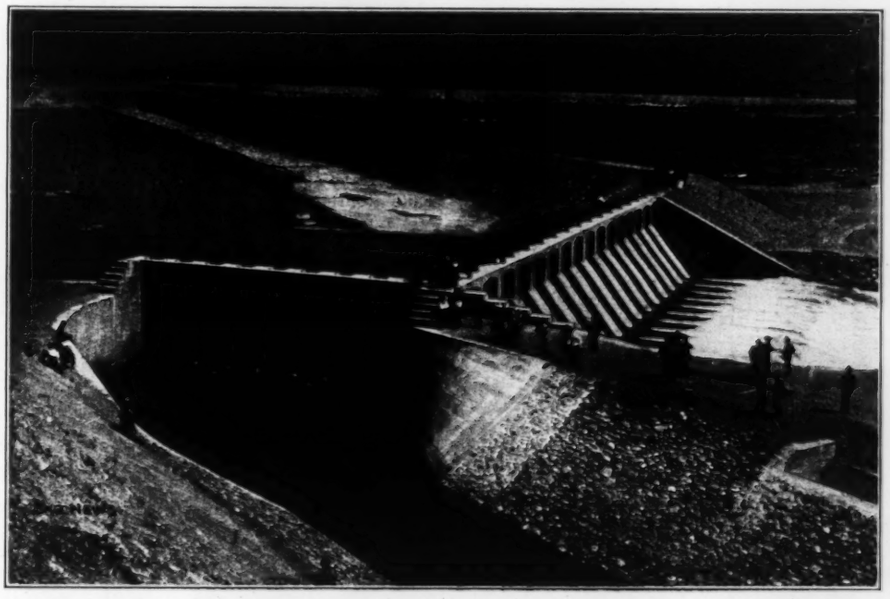
## THE TRUCKEE-CARSON PROJECT OF THE UNITED STATES RECLAMATION SERVICE.

By W. P. Hardesty,* C. E.

The territory included in the Truckee-Carson Irrigation Project is situated in Western Nevada. The major portion of the water for this project is derived from the drainage basin of the Truckee River, while the lands to be reclaimed are mostly within the basin of the Carson River, so that the project involves a union of the two. The principal lands to be reclaimed lie in Churchill and Lyon counties. The territory is traversed by the Ogden Route of the Southern Pacific R. R., and also by a branch running from Hazen to Tonopah.

The average annual rainfall over most of this territory is 5 to 6 ins. The climate is mild, and the proportion of sunshiny days is high. Conditions are favorable for the raising by irrigation of the ordinary crops of the temperate zone.

This project, in its ultimate plan, will involve the reclamation of about 350,000 acres of land, at an estimated cost of $9,000,000. The more immediate object is the reclaiming of about 200,000 acres in the Carson Sink Valley, reaching from the low divide between Wadsworth and Hazen, southeasterly to Carson Lake and easterly to Stillwater. The town of Fallon is near the center of the area that is being reclaimed. A general map of the project is reproduced herewith as Fig. 2.



DIVERSION AND HEADGATES ON TRUCKEE RIVER, NEVADA; TRUCKEE-CARSON IRRIGATION PROJECT OF THE U. S. RECLAMATION SERVICE; LOOKING NORTHWESTERLY, JUNE 17, 1905.

The irrigation system so far constructed consists essentially of (1) the Truckee Canal, for diverting the waters of the Truckee River from its lower canyon over the low divide to the Carson Basin and thence to the Carson River; (2) the diversion of the united waters of the Truckee and Carson from the Carson River by the main distributing canals onto the principal bodies of land in Carson Sink Valley; (3) the lateral distributing system, for the further distributing of water to the lands to be reclaimed.

### Construction of the Truckee Canal.

The Truckee Canal is designed for the conveyance of about 1,200 sec.-ft. of water from the lower Truckee Canyon over into Carson Basin and to Carson River, and also for about 200 sec.-ft. additional in the canyon to a convenient point for a branch to reach the Pyramid Lake country.

The canal is 30.9 miles long, divided into three divisions at the 6 and 13-mile points. The divisions are numbered 1, 2 and 3 from the head. An important part of Division 1 is the diversion dam and head works. There are several expensive structures on Divisions 1 and 2, and also three tunnels on the latter. Division 3 is entirely in open country.

Following the principle adopted by the Reclamation Service at the outset, by which constructed works must be of the most permanent character, all the structures are of Portland cement, concrete and iron or steel, no wood being used except for minor parts, as for flash boards.

Proposals for construction were opened by the Secretary of the Interior at Washington on July 15, 1903. There were five bidders on Division 1, and four on Divisions 2 and 3. The following shows range of the total amount of bids:*

| Division. | Highest. | Lowest. | Average. |
|---|---|---|---|
| 1 | $510,236 | $324,967 | $401,577 |
| 2 | 678,985 | 415,020 | 543,910 |
| 3 | 375,500 | 250,700 | 305,443 |
| Totals | $1,564,721 | $990,687 | $1,250,930 |

An explanation of some of the items of contract work, which applies to all work on the project, will here be given. All the cement used is furnished by the United States. Nearly all the concrete is composed of 1 part Portland cement to 3 of sand and 5 of broken stone or gravel. In certain places, such as the tunnel-arches, the proportions are 1:2½:4½. It was found by tests that 1 barrel of cement in the first mixture makes 24 cu. ft. in place, and 22 cu. ft. in the second mixture.

The different classes of excavation are in brief as follows: Class 1, earth; Class 2, indurated material, which can be removed by scrapers after loosening by powder; Class 3, loose rock and slate or other rock which can be removed without blasting; Class 4, solid rock, which requires drilling and blasting.

C. A. Warren & Co., of San Francisco, were the lowest and successful bidders on Divisions 1 and 2, while E. B. & A. L. Stone Co., of San Francisco, were the same on Division 3.

### DIVERSION WORKS.

The headworks consist essentially of a diversion dam across the river, and of headgates at the entrance to the canal. The diversion point is in the canyon about 10 miles westerly and upstream from Wadsworth. The elevation is about 4,200 ft.

The canyon has sides more or less rocky and steep, but the bottom is of some width. It is traversed by the Southern Pacific Railroad (Ogden route), the reconstructed line of which runs quite close to the canal in places. At the diversion site the river is near the south side of the canyon, and a levee or earth embankment on the north side is needed to piece out the dam to a connection with higher ground.

The dam and headgate (front page view and Figs. 3 and 4) are built as one structure. The dam runs squarely across the river; the headgate is placed at right angles to it, extending upstream from the south end. The entire structure is of concrete, with the addition of what steel and cast iron is needed for strengthening it, and for gates, etc.

DAM.—The dam is designed for the passage of water through it, similarly to a headgate. It is 155 ft. long between abutments. From the main foundation rise 15 piers, to serve as posts for the regulating gates, 16 in number, as shown in detail by Fig. 4.

The foundation is 8.83 ft. thick, and 30 ft. wide, up and down stream, by 171 ft. long over all. It rests on the natural bed of tight gravel and boulders. The excavation was carried to an

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*The original schedule of quantities and a full abstract of bids thereon, and also the specifications and contract for the Truckee Canal work, may be found in the Proceedings of the First Annual Conference of Engineers of the U. S. Reclamation Service, page 198 et seq. (Washington, D. C.; U. S. Geological Survey.)

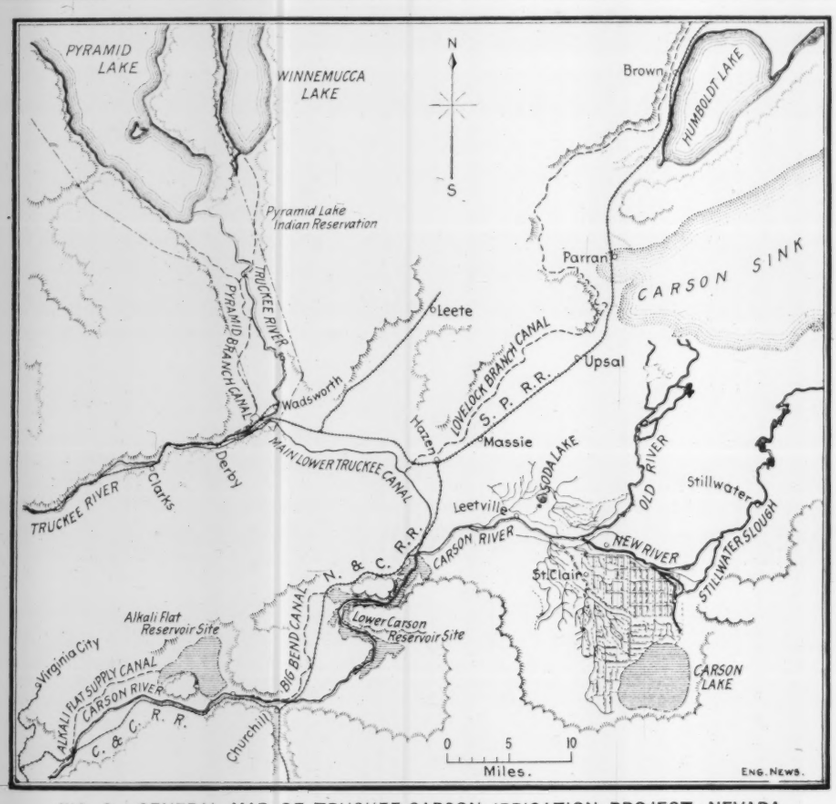



FIG. 2. GENERAL MAP OF TRUCKEE-CARSON IRRIGATION PROJECT, NEVADA.

average depth of about 4 ft. below the bed of the river, which was about 145 ft. wide. There was then driven, about 2 ft. down stream from the upper line of the foundation, a row of Friestedt interlocking steel sheet piling. The channels are 15-in. (⅜-in. metal), weighing 33 lbs. per lin. ft., and the piling is 12 ft. long. The piling was driven for a distance of 185 ft. across the river and into the banks. Though the bed has many large boulders, there was not much difficulty in driving, boulders as much as 1 ft. thick being cut through; but there were some much larger ones which had to be blasted out. The metal was little battered by the hardest driving with hammers of 2,200 and 2,800 lbs., having a fall of 16 to 18 ft. The piling projects up into the concrete foundation from 2 to 5 ft. (the latter at the ends of the dam), depending mostly upon the difficulty of driving. The contract price (piling in place) was $29 per lin. ft. of the row.

The concrete foundation was strengthened as follows: There was imbedded near the base a grillage of 60-lb. railroad rails consisting of 7 longitudinal lines and 31 cross lines, forming 5-ft. squares. In these squares were laid, in the soft concrete, boulders to act as binders between the finished layers.

On the down-stream side of the foundation the river channel was excavated to a depth ranging from 5 ft. next to the foundation to 2 ft. at the lower end, to a distance of 30 ft. down-stream, and filled with large stones, some of which were 3 to 4 ft. through. The surface of this riprap was smoothed off, to serve as a pavement. This provision prevents scouring away of the river bed by flood waters passing through the dam, as their velocity is quite high. On the up-stream side a similar protection, with somewhat less dimensions, is used. At the up-stream and down-stream sides a concrete cut-off wall is carried below the bottom of the foundation to a depth of 2 ft.

Spaced 10 ft. c. to c. along the dam are the piers, each of which is 18 ft. long on the base by 5 ft. wide. The up-stream end is semi-circular, and the down-stream end is sloped down to a toe at the foundation.

It may here be stated that the concrete piers for all dams and headgates so far built on the project have a gravity section, except, of course, where a steelframe work is used with them. They are designed so that the center of pressure comes within the middle one-third of the base.

Although in this design no dependence is placed on the tensile strength of the concrete at the junction of the piers and their foundations, especial pains was taken during construction to have a perfect bond—accomplished by leaving the top of the foundation directly under the piers depressed for a few inches (and also well roughened) before starting the latter.

The piers are 15 ft. high, and the top is aimed to be the high-water mark. On the top of each is a smaller pier, 5.25 ft. high, for the support of the gear for lifting the gates. Running through the coping of these, and extending along the line of the gate shafts, are two lines (157 ft. each) of 7-in. I-beams. These beams support the lifting gears and also serve to reinforce the flat concrete arches that extend from pier to pier. The I-beams are well anchored to the piers, on account of the great upward pressure that may be produced by closing down the gates when there is a large friction to overcome.

The 16 gate openings are each 5 ft. in the clear between the piers. Each gate is virtually composed of three sections: (1) the lower gate, used alone for the ordinary regulation of water; (2) the upper gate, called into action only when a large stream is required to pass; (3) the flashboards, which may be removed for passage of extreme high water. The lower gate is of cast iron 1¼ ins. thick, strengthened by radial ribs, and has lugs cast on the back for receiving the screw stem. The upper gate is of cast iron 1 in. thick, reinforced by rectangular ribs. The two gates together give a total clear opening 10 ft. in height. Their combined weight is about 3,000 lbs. They run in cast iron guides anchored in the concrete piers. All bearing surfaces of gates and guides, including the contact between the back of the lower gate and the front of the upper one, are machine-faced. Above the upper gate is a series of five flashboards, each 3 × 12 ins. × 5 ft. 8½ ins., with edges bound with strap iron. When removed these give an additional opening of 5 × 5 ft.

The operation of the gates is as follows: The lower gate is raised directly by the screw stem. It slides up the front of the upper gate until it reaches its limit (4¾ ft.), when it strikes the horizontal flange projecting from the top of the upper gate, when the further movement raises both gates. The flashboards can be pulled out at the top, one by one, as the double gate is raised. The total height of each opening is 15 ft., and the 16 openings give a total waterway of 1,200 sq. ft. The greatest observed discharge of the river is about 9,000 sec.-ft.

The screw stem of each gate passes up between the I-beams (before described) and into

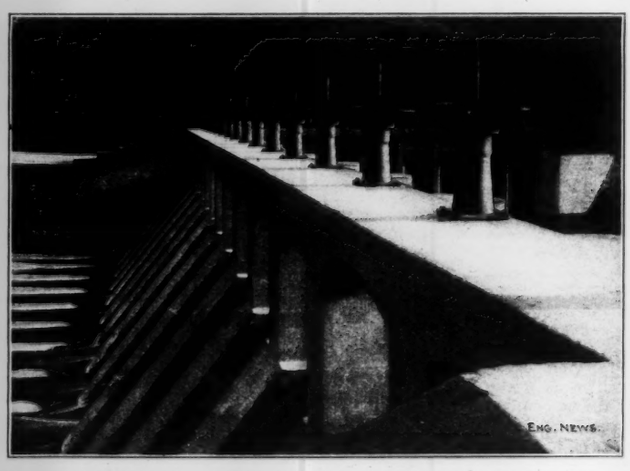


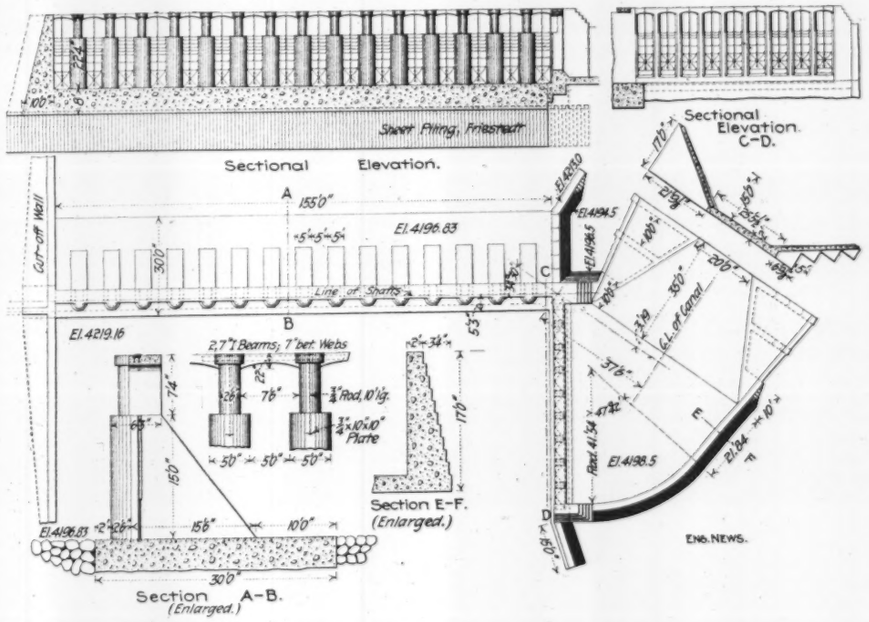

FIG. 3. TOP VIEW OF TRUCKEE RIVER DAM, SHOWING GATE-OPERATING MECHANISM; LOOKING SOUTHERLY, TOWARDS HEADGATES.

FIG. 5. VIEW OF TRUCKEE-CARSON CANAL IN HEAVY CUT, DIVISION 2.

the pedestal or stand. The stand is of cast iron, and has bevel gearing operated by a hand crank. It has two sets of ball bearings, in which the balls run in grooves. One set of bearings takes the downward pressure, which is the sum of the weight of the gate and the friction due to pressure, etc., to be overcome. The other set is to take the upward pressure or resistance, which is the difference of the foregoing factors. The screw stem is 2½ ins. in diameter, double-threaded, with a pitch of 1½ ins. It runs through a bronze nut or socket, set in the stand. The stands, complete with stems, cost $192.50 each, in place, based on a price of $135 for the stand and $40 for the stem (what they cost the contractor), plus 10% for handling and setting.

The gate sills are 4 × 4-in. Oregon pine, set flush in the concrete foundation. They allow of a closer contact than iron.

Beyond the north abutment of the main dam an earth embankment is run out to a connection with the higher ground. This embankment, which is deflected up-stream about 45° from the line of the dam, is 1,160 ft. long and varies in height from 27 ft. (near the dam) to 2 ft. It is 10 ft. wide on top, with a slope of 3 to 1 on the up-stream and 2 to 1 on the down-stream side. The material used was the silt, sand and gravel composing the formation just above the embankment. It was put up in layers by scrapers, but not wetted or rolled. The connection with the back of the concrete abutment, which is aided by use of a projecting tongue forming a cut-off wall, was thoroughly well puddled. The up-stream face of the embankment is paved with 1 ft. of riprap up to 3½ ft. in elevation above the high water mark of the back water basin. The top of the embankment is 3 ft. above the high water mark.



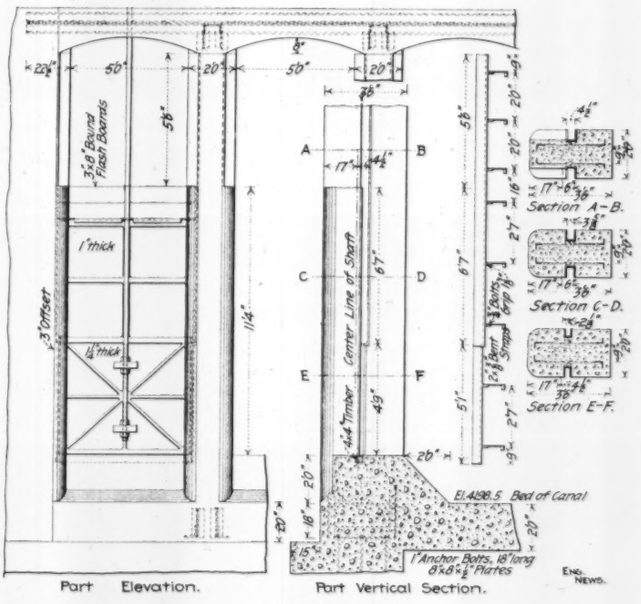




FIG. 4. DETAILS OF TRUCKEE RIVER DIVERSION DAM AND HEADGATES.

HEADGATES. — The supporting structure of the headgates (also shown in detail by Fig. 4) is an extension of the south abutment of the dam. There are nine gates, 7 ft. c. to c., and each having a clear opening of 5 ft. The framework of the structure directly supporting the gates is of steel, consisting of eight posts and one main girder. The girder rests on top of the posts and spans the space between the end walls. Its principal office is to take about one-third of the horizontal, down-stream pressure on the posts, due to the full head of water against the gates, the other part being taken at their feet. The girder is built up, and it has a depth of 3 ft. (placed horizontally) and a length of 63¾ ft. The posts are built up somewhat similarly to the girder, but have lacing instead of cover plates on the back of the angles. This steel framework support is embedded in concrete, posts of narrow section being thus formed, while the girder—besides being filled with concrete and incased to a depth of 4 ins.—has a flat arch formed underneath it over each gate opening. The completed structure, in external appearance, is concrete of very light construction.

The system of gates is practically the same as for the dam, but there are only two flashboards (8-in.) for each gate, giving a total height of 11.33 ft.

The main concrete sill of each gate is 2⅔ ft. above the bed of the canal and 3⅔ ft above the floor of the dam. This is to favor the sluicing through the dam of sand and silt that accumulates in front of it. The bed of concrete at the sill is about 6 ft. thick. On the side next to the river a curtain wall or cut-off wall is carried well down, to prevent the entry of water underneath the headgates. The lower face of the sill is sloped down at an angle of 45° to the bed of the canal, which is here a concrete floor 2 ft. thick. The head of the canal for about 65 ft. acts as a receiving basin, and in the last 35 ft. a transformation to the regular canal section is made by means of converging sides of warped surfaces, the side slopes changing from vertical to 1½ to 1, and the bottom width from about 55 ft. to 20 ft.

Just below the headworks is the first spillway of the canal. It consists of a spillway crest, one end of which is shown in the view on the first page, over which the water falls into a connected small ditch for return to the river. The crest is at the high-water mark of the canal, 13 ft. above the bottom. The spillway is built in the lower bank of the canal, and it has a length of 100 ft. It is for the close regulation of water, when too much may be turned in at the headgate. The cost, not including cement, was $522.

To divert the river around the dam site a temporary dam, consisting of three rows of 12-in. piles well braced together and with sheet piling on the up-stream side, was first built. On the up-stream side of the sheet piling were banked sacks filled with silty material, backed with earth, while on the down-stream side was placed a supporting bank of earth and boulders. The contractor was not paid directly for the dam, as it was considered an incidental to the work of putting in the permanent dam.

The dam turned the river into the temporary flume, on the north side of the river. This was 340 ft. long, 28 ft. wide, 6 ft. deep at the upper end and 4 ft. at the lower, and it discharged into an earth section which returned the water to the river. This flume was called on to carry as much as 2,000 sec. ft.

## CANAL EXCAVATIONS AND STRUCTURES IN THE CANYON.

The portion of the Truckee Canal in the canyon represents the most difficult piece of work and the greater part of the expenditure in the construction. It includes all of Division 1 (six miles) and four miles of Division 2. The sides of the canyon are of varying degrees of slope, and the formation is quite heterogeneous, consisting of various kinds of loose material and rock. The only real hard rock is a kind of trap rock. Much of the formation is so open and porous in places that it is not well adapted for holding water. The only clayey matter present is a fine silt, a characteristic deposit in the old lake bed of all this region. It is the only natural substance available for silting up the sides and bottom of canals, but it exists in such quantities that the canal can be made unusually tight.

The dimensions and grades of the canal are so adjusted that the calculated velocity ("n" = .025 in Kutter's formula) with the full depth of water (13 ft.) in earth sections is at, or a little less than, 3 ft. per sec. This applies to the entire canal. There were a number of standard sections used, as adapted to different materials in excavation, varying transverse slopes of the ground, etc. A very common section used on Division 1 has a 20-ft. base, upper side slope of 1 to 1 and lower one of 1½ to 1, with grade of 1 in 6,500 (0.000154) and velocity of 2.95. This is used in fairly firm material. Where the material was light the bottom was made 18 ft. and the slopes 1½ or even as much as 2 to 1. On Division 2 the width of the different sections was made somewhat less, as the required capacity reduces from 1,400 sec.-ft. to 1,200 sec.-ft. at the end of Division 1. The grade used on Division 1 throughout is 1 in 6,500. On Division 2 the same is used, except that in rock sections it is changed to 1 in 2,400 and in tunnels to 1 in 1,500. The embankment used for the entire

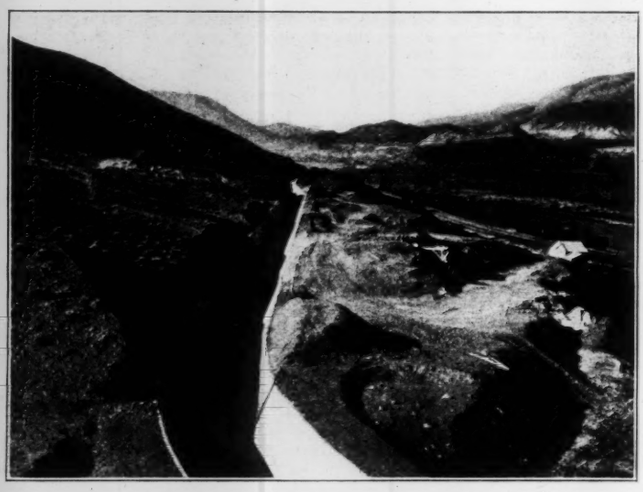


FIG. 6. LINING IN SIXTH SECTION, LOOKING UP STREAM.

FIG. 8. NINTH SECTION OF LINING; ROUNDING WADSWORTH POINT AT MOUTH OF CANYON.

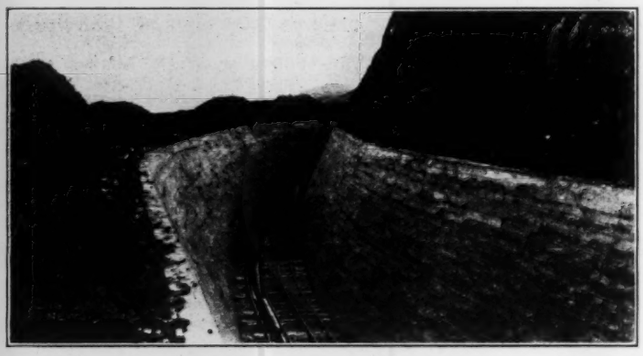


FIG. 7. LINING IN ROCK CUT, SEVENTH SECTION, LOOKING DOWN STREAM.

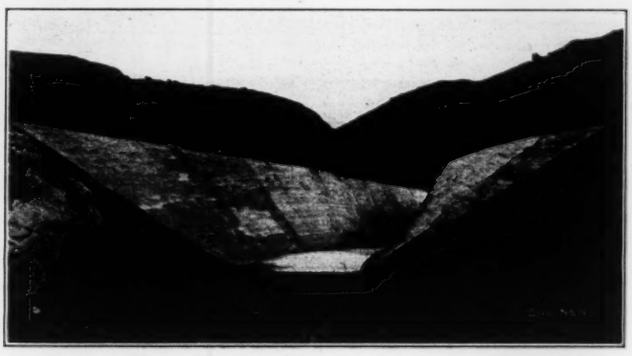


FIG. 9. JUNCTION OF EARTH AND CONCRETE-LINED TUNNEL, SHOWING WARPED SURFACE IN LATTER.

FIGS. 6 TO 9. CONCRETE-LINED SECTIONS OF TRUCKEE CANAL.

length of the Truckee Canal has a top width of 8 ft. and a height of 15 ft. above the bed, which gives a clearance above the water line of 2 ft. The slopes are 1½ to 1, both sides, in places made 2 to 1 next to the water section. The ground slopes toward the river, to the left, all the way through the canyon. For nearly all of the distance no bank is needed on the upper side, but whenever the upper cut falls below 15 ft. the bank is used. This (in earth) makes a very uniform section for the smooth flow of water, and also reduces the area exposed to seepage and evaporation.

HEAVIEST CUTS AND FILLS.—On Division 1 the heaviest center cut is 51 ft. At only a few points does the bed of the canal require a fill on the center line to bring it up to grade. In the side-hill work a heavy cut on the upper side of the excavation is often accompanied by a considerable fill at the lower toe of the embankment. The largest of the single cuts (segregated from adjoining lighter work) occurs right at the lower end of Division 1, where in a length of 1,050 ft. the excavation amounted to 141,000 cu. yds. The section used here is 18 ft. base, lower slope 2 to 1, upper slope 1¾ to 1. The heaviest cross section in this cut runs 218 cu. yds. per lin. ft.

On Division 2 the center cut at two places is 55 ft. At one of these the cut on the upper side is 105 ft., and the yardage per lin. ft., 179. At both places the canal has a base of 13.4 ft. and slopes of 1½ to 1. At only a few places is there a fill on the center line. The largest single cut contains 80,000 cu. yds. in a length of 900 ft. Fig. 5 shows the heaviest of the cuts.

LOCATION OF LINE.—In the canyon the sharpest curves used for the location were 20°, of which there are quite a number. Almost two-thirds of the total number of curves are 15°. Approximately 50% of the canal line is in curvature.

In several places the canal runs just above the reconstructed line of the Southern Pacific R. R. Great care was taken with these places to make the canal bank absolutely proof against considerable leakage and breaks. The channel was usually lined with concrete where in bad material.

On Division 2 there are three tunnels, Nos. 1, 2 and 3, with lengths of 901, 308.7 and 1,515 ft., respectively. These are through prominent ridges, the points of which (for Nos. 1 and 2) are cut by the railroad excavation so as to leave a steep bank next to it. The use of the tunnels avoids these points and much steep side-hill, and also shortens the distance.

CONCRETE LINING IN CANAL.—The plan of lining the water-section of a canal, although it has been used on small canals in Southern California, is somewhat of an innovation for large irrigation canals, and it is a construction that is being used quite freely by the Reclamation Service. In the Truckee canyon concrete lining is used (see Figs. 6 to 9) under a variety of circumstances: (1) In rock excavations to make a much smoother section and thus allow of a narrower cross-section and consequent reduction in yardage; (2) in very broken, seamy or fissured rock which would allow much leakage; (4) in places where leakage or washouts might have serious consequences. There are several different sections used. The value of "n" was taken as .015 in calculating the velocity. In one the side slopes are 1 to 1, used only where excavation is either wholly or partly in heavy gravel and boulders. In another the slopes are ½ to 1, entirely used in rock cuts. In one place lining with ¾ to 1 slopes is used. In another place only the bottom and lower side are lined. The standard thickness of lining intended to be used was generally 6 ins., but in one place (in a rock excavation) 4 ins. was adopted.

All lining is brought up to an elevation 2 ft. above water line, at the grade for the top of the bank. Both sides were brought up at the same time, as cross-bracing could be used between their forms. The concrete was brought in layers of about 1 ft. and tamped with spade tamps. Pockets or caved-in places in the excavated slope were usually brought out to the proper line back of the concrete by filling with broken stone, in advance of the lining. This back-filling was done by hand, as carefully as in paving or in a dry wall, and was classified as riprap.

For much of the lined canal a "binder" was used. This consists of a horizontal projection from the back of the lining, usually about 6 ins. thick, and extending back to the earth or rock side. Usually only one binder was used, generally placed along the mid-section of the side (sometimes both) which appeared to need it. In bad places two binders were used, at vertical intervals of about 5 ft. The binder serves (to some extent) to anchor the slope-lining, to make the lining less liable to rupture caused by pressure of loose materials behind it, and to break up the continuity of moving or sliding ground behind.

The concrete was made of the regular proportions of 1, 3 and 5. Some small temperature cracks have appeared. Where the concrete was laid during the summer these show at fairly regular intervals of 30 to 40 ft. Where laid during the winter, the cracks are about 200 ft. apart.

The amount of concrete in the lining per lin. ft. of canal varied all the way from 0.6 to 1.4 cu. yds., depending on the width and slopes and

on the thickness of lining. On the section with 20-ft. width and ½ to 1 slope a thickness of 6 ins. requires 1 cu. yd. The total cost to the Government of all items for the concrete was about $9 per cu. yd.

On Division 1 there are five stretches or sections of lined channel, having an aggregate length of 5,016 ft. In all but one of these (which has ¾ to 1 slope) the side slopes are ½ to 1, and in all the bed width is 20 ft.

On Division 2 there are four stretches of lining, having a total length of 7,314 ft. In three of these the cross-section has a bed width of 8.9 ft. and slopes of ½ to 1—the grade being .00042; in the remaining one the bed width is 10 ft. and the side slopes 1 to 1, the grade being .000154.

The thickness of lining on the sections varies, and often different portions of the same section have different thicknesses, according to the nature of the formation. The thickness aimed at proved to be a *minimum* thickness, as the *average*, on account of shattered surfaces and slips in the excavation, was much greater. In rock cuts, especially, it is practically impossible to excavate all material back to a clearance line without recesses extending considerably farther. On all the sections where the ½ to 1 slopes are used, the formation is solid rock; on the two with flatter slopes the material was also largely rock.

On the third section on Division 2 only the lower side and bottom are lined. The lower side (partly in embankment) was lined to give a smoother channel, and also on account of some weak places in it. The bottom was lined to give a smoother section. The side slopes are ¾ to 1.

At the lower end of all the lined sections the adjoining ordinary canal was paved or riprapped for a distance usually of 25 to 100 ft., to prevent erosion by the swifter current coming out of the lined section. This riprap and that used behind the lining formed quite an item of the total cost of lining. The following table gives a summary for each division, made up from the cost data for each section of lining:

| | Div. 1. | Div. 2. |
|---|---|---|
| Length, ft. | 5,016 | 7,314 |
| Concrete: | | |
| Cubic yards | 6,100 | *9,956 |
| Contract cost ($6 on Div. 1; $5.50 on Div. 2) | $36,600 | $54,758 |
| Cement† | 18,300 | 31,320 |
| Total cost | 54,900 | 86,078 |
| Cost per lin. ft. | 10,945 | 11,769 |
| Riprap‡: | | |
| Cubic yards | 4,284 | 2,541 |
| Cost ($4 on Div. 1; $3 on Div. 2) | $17,136 | $7,623 |
| Total cost concrete and riprap | 72,036 | 93,701 |
| Total cost per lin. ft. | 14,360 | 12,811 |

WARPED SURFACES.—The transition from the ordinary canal section to concrete-lined sections (see Fig. 9), and from both of the above kinds to tunnels or to structures, was effected in most cases by the use of warped surfaces.

The warped surface, mathematically considered, is the surface of a hyperbolic paraboloid. It can be formed by either of two sets of directrices, there being two in each set. The directrices are two right lines not in the same plane. For practical application to the canal work a set is so taken that one directrix is the straight line at the top of the warped slope, while the other follows the edge of the base of the canal. These two lines are divided into the same number of equal parts, when lines joining the corresponding points on them form *elements* in the warped surface.

The two directrices are drawn in plan, according to the outline decided on for the whole surface, and are divided into spaces about 2 or 3 ft. long, the corresponding points being joined by straight lines. The latter represent in plan certain elements of the surface, the slope of which is quickly determined. The concrete forms can then be designed and built accordingly, the elements being controlling lines to be followed by the nailing pieces, while the gradual curving between them can be made by springing the plank lagging.

Where no lining is used the excavated slope is easily made to follow the general outline of the warped surface by cross-sections at more frequent intervals. In such cases a distance of as much as 100 ft. is often given to the transition of section. In lined sections and adjoining structures the change is usually made within 30 to 50 ft. In the lined portions of canal before described the warped surface approaches are included in the lengths given.

TUNNELS.—The tunnels on the Truckee canal, four in number, are all on Division 2. In inviting bids three methods of lining tunnels were set forth in the specifications, as follows: (1) Where the material requires temporary timbering during excavation and permanent lining with concrete afterwards, the timbers remaining in the concrete; (2) where the material is of such nature as to stand until lined, or to allow of the timbers being moved when the lining of concrete is put in; (3) where the material is hard rock, and can be plastered with a coat of cement plaster. The first method was used on all the work except for No. 2 tunnel, where the second method was used. The finished section of concrete by either of methods (1) or (2) is 12 ft. wide, 12 ft. high to the springing line, and has a three-centered arch 3.35 ft. high. The water section is 13 ft. deep, with an area of 155.9 sq. ft.

The grade through the tunnels is 1 in 1,500, and the calculated velocity, with value of "n" in Kutter's formula = .012, is 8.10 ft. Tunnel No. 3 has a slightly different section. The upper approach to each tunnel has a fall of 0.2 to 0.4 ft. (according to length), to accelerate the velocity for the tunnel, while the open canal for a short distance below the exit end is paved, to prevent scour of bottom and sides until the velocity is reduced.

In method No. 1 the timbered sets are of 8 x 8 in. lumber, each forming an arch of four segments; sets spaced 2 to 6 ft. on centers, according to pressure. The space between the timber sets and the clear space for 4 ins. inside of them is filled with concrete. At the center of the arch this clear space is made about 8 ins., giving a total thickness of 16 ins. The concrete floor is 4 ins. thick. Contract prices for tunnel work were for the completed tunnel section, the unit being 1 lin. ft.

In driving, all drilling was by hand. The tunnels were all dry. The timber sets were of soft native pine, and they were spaced as widely as deemed safe, one reason for this being a desire to retain the full concrete lining as far as possible.

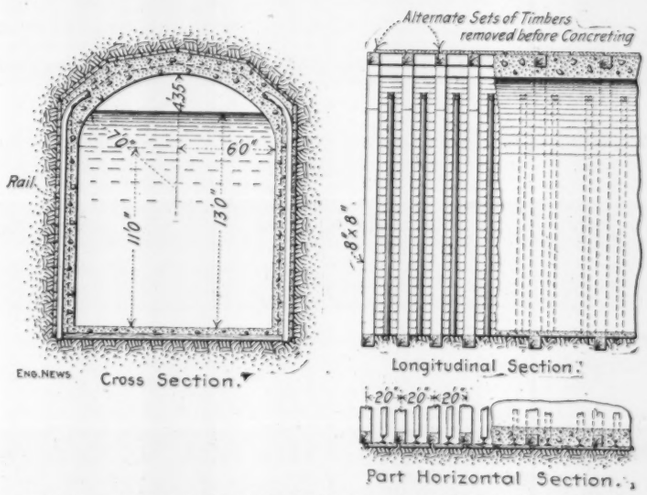



FIG. 10. METHOD OF LINING A PORTION OF TUNNEL NO. 3, ON TRUCKEE CANAL.

(The remainder of the lining of this tunnel was the same as here shown, except that the rails were omitted.)

*Tunnel No.* 1 is 901 ft. long. About 70 ft. of the upper end is on a 20° curve. Beginning at about 160 ft. in from the lower end another 20° curve extends inward for about 160 ft. Under natural conditions this tunnel would not have been built, though it saves much side-hill work and some distance; but the existence of the railroad (which makes a heavy cut through the same ridge) required it. The portal cuts are about 80 ft. deep at the center. The material encountered was a dark, hard, flinty rock, with many seams and slips. The total cost was $39,053.

*Tunnel No.* 2 is 308.7 ft. long, all on tangent. It was constructed by the second method, i. e., without timbering. The material encountered was a red rock, not hard, but compact, tough and without seams, so that it broke up "short" in blasting and could be cut close to line. The total cost was $14,007.

*Tunnel No.* 3 is 1,515 ft. long. The portal cuts are 35 to 40 ft. About 150 ft. at the upper end and a short distance at the lower end are on 15° curves. The tunnel was built by method No. 1, with a slight modification of the cross-section first designed. The height to the springing line was made only 11 ft., which allowed of a shorter radius (only 7 ft.) being used for the central part of the arch. The arch lining was also made much thicker. The method used for lining a portion of this tunnel is shown by Fig. 10.

The material driven through was earth all the way. For about 150 ft. at the exit end (east end) there was a loose, nearly pure sand, which ran very freely. In driving the heading through this it was necessary to use a temporary form of timbering in advance of the permanent timbers. Instead of erecting the sets and then placing the lagging, the lagging was kept 3 or 4 ft. in advance of the sets by driving it forward from the last set. The operation of placing the successive lengths might be said to resemble that of shingling, only that the order is exactly reversed—each row going *under* the preceding one. When the excavation reached within a foot or two of the front end of the last row another timber set was placed within it, leaving sufficient space between it and the lagging (2 ins. or more) to insert the boards of a new set, which were driven forward into the breast of the heading until their rear ends reached the timber set.

The permanent timbers advanced with the bench-excavation, and were placed as closely as 2 ft. and even 1 ft. in places. For a portion of the east end the concrete lining was reinforced with railroad rails. For the 150 ft. noted the progress in driving was less than 1 ft. per day. Nearly all the remainder, however, was of a very favorable material, being of silt or cemented gravel that worked easily and stood well. The timber-spacing for this was 4 ft. During one month 472 lin. ft. were driven from both headings together, and 462 ft. during another month. The greatest progress at one end was 294 ft. Following are the items of cost of the tunnel:

| | |
|---|---|
| 1,515 lin. ft. of driving, timbering and concreting, per contract, at $36.70 | $55,601 |
| 3,022 bbls. cement, at $2.55 | 7,706 |
| 280 cu. yds. extra concrete (mostly caused by change to a stronger section), at $12 | 3,360 |
| 255,675 ft. B. M. extra lumber used in timbering, at $30 | 7,670 |
| 9 tons railroad rails, at $60 | 540 |
| Total | $74,877 |
| Cost per lin. ft. | $49.42 |

*10,408 cu. yds. placed, but 452 yds. disallowed contractor because of unnecessary thickness in places, owing to contractor's carelessness in blasting far outside the clearance lines.

†Average cost per cu. yd. of concrete almost exactly $3. Apparently higher on Div. 2 because of the item in foregoing note (*). One barrel of cement, costing $2.55, made on an average 23 cu. ft. of concrete.

‡This includes dry wall filling behind the lining, and also paving of adjacent portions of canal, mostly at the lower end.

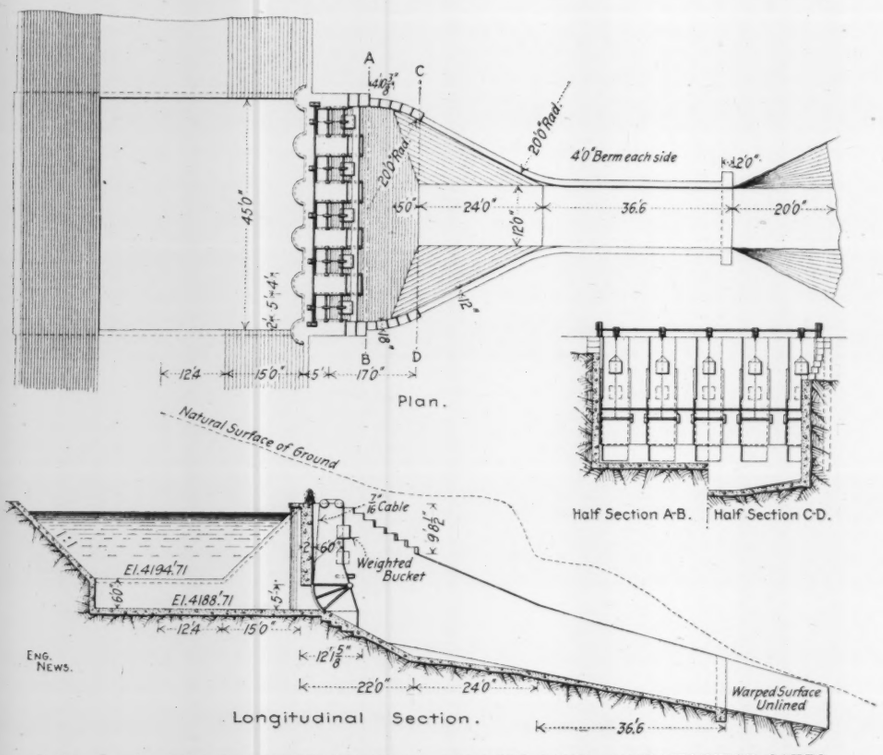



FIG. 11. DETAIL OF WASTEWAY NO. 1. TRUCKEE CANAL, WITH TAINTOR GATES.

In the totals for cost of this and the other tunnels, the cost of engineering (including inspection) is not included.

*Tunnel No. 4* is not on the canal itself. It is required to pass the water of a wasteway under the railway track to discharge it into the river. The water drops down to the head of this tunnel from the wasteway through a shaft 49 ft. deep. The shaft was excavated and lined by the contractor, for which he was allowed the regular tunnel unit price for 1½ times the depth of shaft. The tunnel is 115 ft. long. It was built by method No. 1, and the same section of lining as in tunnel No. 3 was used. The total cost of shaft and tunnel was $8,040.

To make the proper transition of water section from canal to tunnel, each of the three main tunnels was differently treated. This change is made in the concrete approach or portal, forming entry and exit chambers at the upper and lower ends, respectively. In tunnels Nos. 1 and 3 the chambers are 40 ft. long and in No. 2 they are 25 ft. In No. 1 the change is made by straight surfaces instead of warped ones. From the portal opening, flaring vertical wing walls are carried back 40 ft., when they contain the same width (58.4 ft.) as between the tops of the slope-walls. The slope-walls are produced forward on the same plane to intersection with these wing walls, forming on each side an obtuse, re-entrant angle along a line sloping from the top of the wall (at the upper end) to the lower corner of the tunnel-section.

On Tunnel No. 2 an open section of same width as tunnel is carried back for 19 ft., when the vertical walls are flared out by turning to right angles with a curve of about 6 ft. radius. The slope-walls of the canal section intersect each of the cylindrical surfaces formed in an approximately elliptical curve, forming a re-entrant angle. As the canal section (which is lined) adjoining the entry chamber has side slopes of only ½ to 1, the transformation is not so abrupt as might be thought. At the exit end, where the material is all earth and where square wing walls of some length are needed to connect the circular walls with the slope walls (on account of the greater width of canal), the circular walls are reinforced with ½-in. galvanized iron cable, stretched out at certain vertical intervals around the wall, being imbedded near its face.

In Tunnel No. 3 the transformation is made by warped surfaces, which is the method used for all changes between canal sections.

CANAL STRUCTURES.—In the canyon there are, besides the headworks, three very elaborate structures. Two of these are wasteways, and the other one is the headworks for the taking off of the Pyramid Branch Canal.

UPPER WASTEWAY.—The first or upper wasteway (No. 1; see Figs. 11 and 12) is located at 4.6 miles from the head, in the fifth section of lined canal. A basin is formed by dropping the canal bed 6 ft. for a length of 45 ft. and by widening it on the lower side, making a chamber 45 × 36 ft. on the bottom and causing a depth of 19 ft. when the canal is full. The depressed basin serves as a sand or sediment trap, from which the sediment is easily flushed out through the gates. The supporting structure for the gates is of concrete and is very substantial. It is on the lower side of the canal.

In the wall forming the lower side of the canal are five gate openings, each 5 × 5 ft., with bottom flush with the bottom of the basin. Each of these is regulated by a gate of the Taintor pattern. This gate consists of a circular arc revolving around a horizontal shaft to which it is attached by radial arms, the whole forming in outline a sector of a circle. The arc is convex towards the water pressure, which is transmitted as thrust by the radial arms directly to the shaft.

The gates here are made as follows: The center of the shaft is at the same level as the top of the gate opening. The radius to the outside or bearing surface of gate is 7 ft. 5⅞ ins. The net length of the arc is 5 ft. 5⅜ ins., it subtending an angle of 41° 53′. The steel shaft is 4 ins. in diameter and 7 ft. 1¾ ins. long. From the shaft radiate three cross-frames constructed of 3 × 3 × ¼-in. angles, the outer ends of which support the circular part of the gate. The latter is built up of angles, plates and 5-in. I-beams. When closed the upper and lower ends and the side-edges of the gate have contact with guide strips set in the concrete. All these contact surfaces are of bronze. They only give contact, to make watertight; the actual weight of the main part of the gate (when closed) is taken by a 6 × 6-in. timber set in the floor, on which the bearing edge of the gate rests, with tangential pressure.

The gate shafts have cast-steel bearings bolted on to the sloping back of the concrete piers. As the pressure against the bearings is outward (away from the supports) they have to be very strongly anchored to the concrete. Each gate transmits the maximum hydrostatic pressure against it—between 27,000 and 28,000 lbs.—and there is a possibility of having to take additional pressure caused by the wedging effect of par-

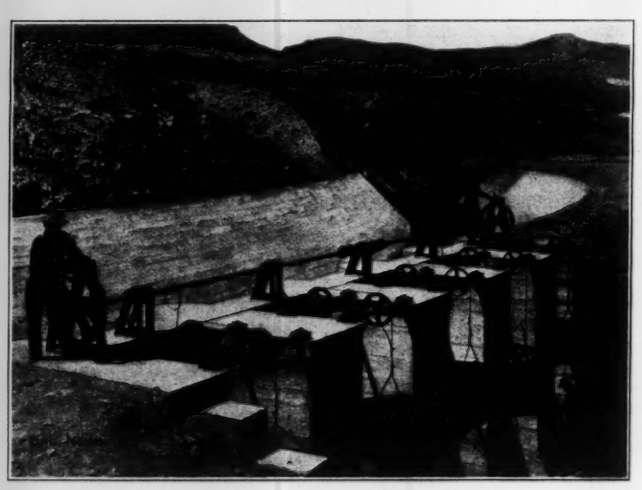


FIG. 12. WASTEWAY NO. 1, TRUCKEE CANAL, SHOWING MECHANISM FOR OPERATING TAINTOR GATES.

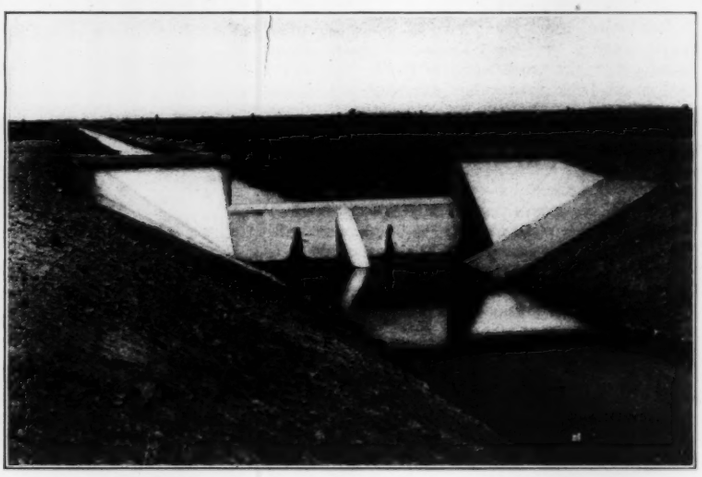


FIG. 17. A SIMPLE FORM OF FALL OR DROP; IN SOUTH-SIDE CANAL.

FIGS. 12 AND 17. MINOR STRUCTURES ON TRUCKEE-CARSON CANAL SYSTEM.

ticles of sand, etc., that may lodge between the contact surfaces of the gate. The gate is raised by an attached wire cable, which extends up to a grooved drum on top of the wall. The drums for all the gates are keyed to one shaft, which is turned by hand gearing at either end. As the power available by this mechanism is small, each gate is counter-weighted as follows: Another wire cable leads from the same point of attachment up to two sheaves set 3 ft. apart. From the rear sheave the cable leads down to a bucket of about 15 cu. ft. capacity, which is filled with water to give the required weight.

The water-pressure against the gate does not increase the resistance to lifting, but rather tends to decrease it by easing the contact between the gate and its guides. The principal advantage claimed for this type of gate is that it can be raised quickly, as may be desirable in emergencies. A disadvantage is the very close fitting required to give perfect contact between the bearing surfaces, which is made all the more difficult by reason of the tendency of increasing water pressure to lessen the contact—the direct opposite of ordinary gates, where the pressure and the contact bearings are on opposite sides. Its use here was decided on somewhat as an experiment.

The set of five gates and all appurtenant parts cost $2,541, f. o. b. at San Francisco. The work of unloading, hauling and erecting in place was done by the canal contractor by force account, costing $261. The total cost (adding 15% to sum of the foregoing for contractor's superintendence, use of tools, etc.,) in place was $3,223, not including freight.

The wasteway was designed to give an outlet capacity of 2,500 sec. ft. with the canal full of water; that is, 19 ft. depth over the bottom of the gates. This was to provide for a quick drawing of water from both directions.

LOWER WASTEWAY.—The lower wasteway (No. 2) is located three miles below the other one, and is in the seventh section of concrete lining. The structure and gates are practically the same as in the first one. The water issuing from the gates pours down a shaft 49 ft. deep into Tunnel No. 4 (before-described), whence it passes under the railroad track, to be finally discharged into the river.

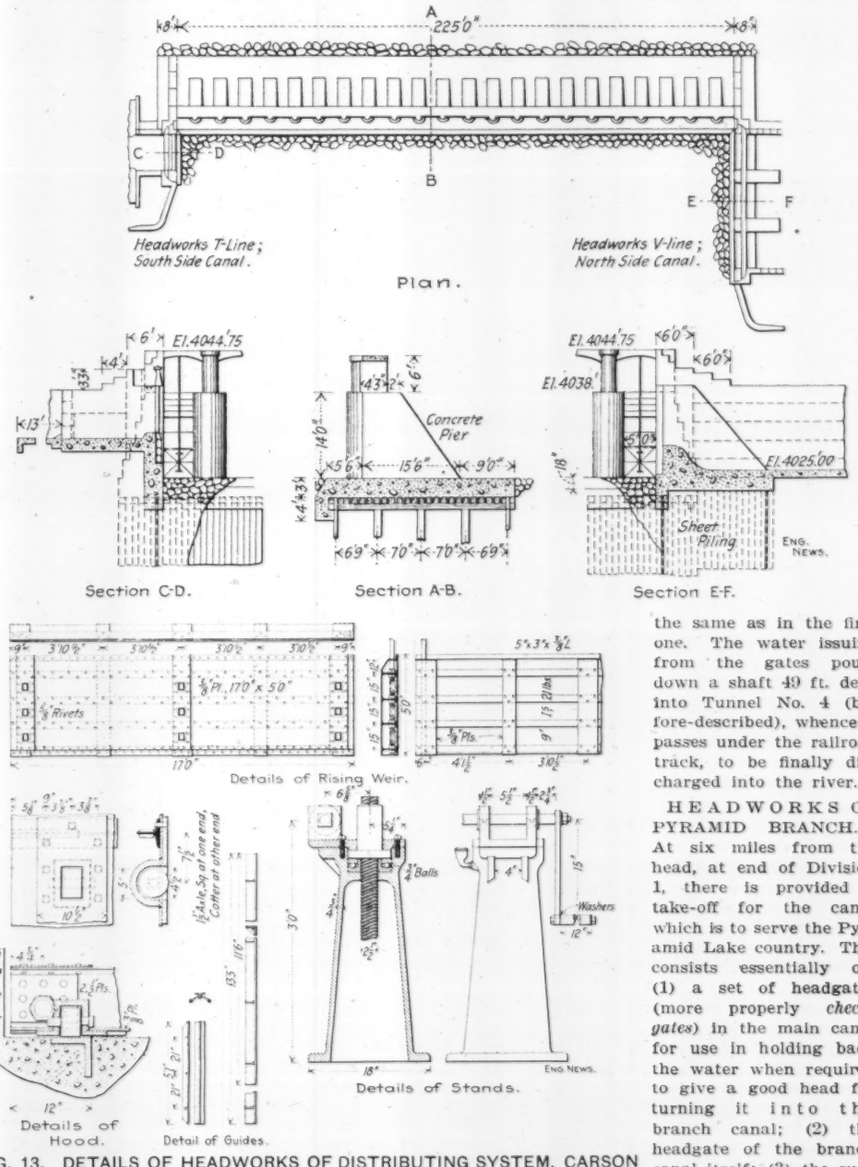



FIG. 13. DETAILS OF HEADWORKS OF DISTRIBUTING SYSTEM, CARSON RIVER; TRUCKEE-CARSON IRRIGATION PROJECT.

HEADWORKS OF PYRAMID BRANCH.—At six miles from the head, at end of Division 1, there is provided a take-off for the canal which is to serve the Pyramid Lake country. This consists essentially of: (1) a set of headgates (more properly *check-gates*) in the main canal for use in holding back the water when required to give a good head for turning it into the branch canal; (2) the headgate of the branch canal itself; (3) the supporting structures, approach-sections of canal, etc. The six gates in the main canal are like those used at the head of the canal. The two gates at the head of the branches are also the same, but no flashboards are used.

The formation in which the structure is built is mostly sand. The four warped surface approaches of the structure were therefore reinforced with ¾-in. round rods and ½-in. cable.

CANAL OUTSIDE OF THE CANYON.

At 10.0 miles from the dam the canal reaches the mouth of the Truckee Canyon. It now makes a large turn to a general southeasterly direction following one side of a bay in the Carson Sink Valley. Construction is much simpler and easier, and no structures are required. The location nearly all lies on the gentle slope that has tapered out from the foothills. The canal finally discharges into the Carson River near the dam-site for a large reservoir (the Lower Carson Reservoir), at 30.9 miles from the head. This terminal point is a little west of south of Hazen, and seven miles distant. As the country is much more open, good alinement in location was possible, and the proportion in curvature is only about 25%. Nearly all the curves are 6°, though there are one 20° and four 15° curves.

The canal has two distinct purposes: (1) to conduct surplus waters to fill the Lower Carson Reservoir (not yet built); (2) to carry water for direct irrigation. The former purpose requires it to maintain its full capacity of 1,200 sec. ft. to the end. At about 13¼ miles from the head the canal crosses over the divide (very broad and illy-defined at this low elevation) that forms the watershed between the Truckee and Carson basins.

For practically all of the distance, except for 1.4 miles in rock work, the grade is 1 in 7,000. In medium material the bed width is 14 ft., and side slopes 1½ to 1. In light material the bed is 12 to 14 ft. and the slopes 1¾ to 1, or else 9 ft. bed with slopes of 2 to 1. The depth of water is 13 ft. on all of the canal. Both banks of the canal are required to be made for nearly all the open-country portion. The usual cut is 6 to 10 ft., with a maximum of 20 ft.

The excavation had a large proportion of material that had to be classified. There were three rock cuts, composed almost entirely of Class 4 material. The longer one of these is 7,500 ft. long, made through lava rock. The material was removed, after blasting, by steam shovels with 38-ft. booms. As first worked, these delivered the rock to a skip on either side, which was hoisted by a derrick on the edge of the cut, to be dumped on the spoil banks. This method did not prove satisfactory, and the derricks were discarded after being used on about 1,000 ft. of canal. The canal-section has a 12-ft. base, slopes of 1 to 1, grade of 1-3333, and a calculated velocity of 3.70.

Though the canal dimensions and grades are adjusted so that the calculated velocity in earth sections does not exceed 3 ft., the very clean and uniform section of this canal will undoubtedly result in considerably greater velocity, as indicated already by the velocity with the canal only partly full. The value of "n" taken as .020 would probably about fit such channels.

Pending the construction of the Lower Carson Reservoir, there was built a temporary wooden flume or chute for carrying the water down the hillside and discharging it into the river shortly below the dam-site. The total cost, including outlet from the canal, was $4,059. The grade of the canal is about 120 ft. above the bed of the river at the dam-site, the elevation of the canal being fixed at its lower end by the necessity of discharging into the reservoir above its water line.

Table I gives the items of complete cost of the Truckee Canal.

**Construction of the Main Distributing Canals.**

The office of the main distributing canals is to divert the commingled waters of the Truckee and Carson rivers from the Carson on to the main bodies of land to be irrigated, in which the town of Fallon is about the center. The diversion for both sides is made at a point about five miles below the Lower Carson Reservoir dam-site. The southside main canal was designed to have a capacity of 1,500 sec. ft., and the north side one of 400 sec. ft. The former has a length of 21.7 miles, besides a branch of 5.3 miles, while the north side canal is 9.1 miles long.

The entire work was divided, for contract purposes, into four schedules, based on the nature of the work. Schedule A (excavations and embankments) was also divided into seven divisions, the first six of which covered the south canal and branch and the seventh one the north canal. The various structures are of Portland

cement concrete. Above the ground practically no wood is used, the gates and appurtenant parts being of steel or cast iron.

Proposals for construction were opened at Reno, Nev., on July 15, 1904. A complete abstract of the bids may be found in the Third Annual Report of the U. S. Reclamation Service (1905), pp. 342-5. In Schedule A bids were invited on each of the seven divisions. The same bidder was the lowest on each of them, though the number of bidders ranged from 11 to 16. The following shows the range of bids:

| Schedule. | Nature of work. | Highest. | Lowest. | Average. |
|---|---|---|---|---|
| A.... | Excavations & embankments ..... ..... | | $195.887 | ..... |
| B.... | Headworks ..... | $109,552 | 52,168 | $86,445 |
| C.... | Spillways, falls and aerial headgates | 89,310 | 43,219 | 64,058 |
| D.... | Highway bridges.. | 15,750 | 4,288 | 7,851 |
| | Total of lowest and successful bids.. | | $295,562 | |

HEADWORKS.—The headworks (Figs. 13 to 15) consist of a diverting dam across the river, and of intakes to the north and south canals. At the diversion point the river lies between rather low banks. The formation is of earth, sand and gravel. The elevation is a little over 4,000 ft.

The dam is of concrete, and in general design, arrangement of gates, etc., closely resemble the Truckee dam. An important difference in the foundations is in the use of a timber grillage. The concrete foundation is 240 x 31 x 3 ft., resting on a floor of 12 x 12-in. timbers in which spaces of 1½ ins. were left between the timbers for flushing in sand to better fill up below the floor, and also to secure a good bond and water-tight contact between the concrete and floor. The latter rests on 12 x 12-in. caps, supported on 12 x 12-in. bearing piles spaced 7 ft. each way. The piles were driven as far as possible in the packed sand and gravel, not over 12 to 14 ft. Under the floor, near the upper and lower sides, were driven two rows of 6-in. sheet piling. The upper row is of built-up piles, each pile of three pieces of 2 x 12, spiked and bolted together, so as to form a tongue and groove 2 ins. deep—the piling being driven so as to form tongue and groove joints.

The dam is 225 ft. long between abutments, and contains 23 openings of 5 ft. each. The construction above the foundation is similar to that of the Truckee dam. The gates are somewhat different, the main feature being in the screw-stem being attached on the *down-stream* side in place of the upper side. The advantage of this is that the stem and connections are usually entirely out of the water, and so can be inspected at any time.

The headworks of the canals are different from those at the Truckee dam. The gates themselves are totally different from the ordinary kind. As they are also used at some other places on the distributing canals, and are of a very novel type, they will be described in some detail.

The gates are really movable weirs, and are hence called "rising weirs." The arrangement consists essentially of a fixed sill or crest at more or less height above the canal grade, and a movable part or gate sliding up and down the face of this, by which the height of the crest can be increased up to a limit near the high-water level. As constructed on this system, the fixed portion is a concrete wall, called *weir wall*, while the movable part is built of steel I-beams and plates, moving by roller bearings up and down the cast-iron guides on the concrete wall and the piers and abutments. The design of all these gates or rising weirs and their operating gear is practically the same.

At the headworks three gates for the south canal and one for the north canal are used, all being exactly the same. Each gate is 17 ft. long over all by 5 ft. high. (See Fig. 13.)

The style of hood used has not proved to be satisfactory, on account of sand, etc., collecting in the housing of the rollers and binding them. For the other structures of the canal system an entirely different design, doing away with the confinement of the rollers, has been adopted.

Each set of rollers bears against a cast-iron guide, set flush in the concrete. The middle guide is placed in the weir wall, and is available for bearing of *all* the rollers only when most of the gate is down behind the wall. As the rollers of the middle set are thrown out of action with the raising of the gate the water pressure is also reduced, so that the design is sufficient. The guides are merely angle bars, with lugs at intervals to which short bent rods are attached for anchoring the guides in the concrete.

The stands for raising the gates are also different from those before described. They are of cast iron, with a single set of ball-bearings. One is placed at each end of the gate. The gate stems are worked by means of worm-gearing. A shaft runs the length of the gate, and at each stand a worm is keyed to it, which works

TABLE I.—SUMMARY OF COST OF CONSTRUCTION OF MAIN TRUCKEE CANAL.

DIV. 1—6 miles—C. A. Warren & Co.

| Work or material. | Schedule quantity bid on[a] | Bid. | Actual quantity. | Amt. earned by Item. | Cont'r's. Total. |
|---|---|---|---|---|---|
| Headworks: | | | | | |
| Excavation, Class 1.....cu. yds. | ..... | $0.23 | 39,731 | $9,138 | |
| Excavation, Class 2.....cu. yds. | ..... | .30 | 862 | 259 | |
| Excavation in water .....cu. yds. | 2,000 | 2.00 | 2,000 | 4,000 | |
| Concrete .....cu. yds. | 3,000 | 6.00 | 3,322 | 19,932 | |
| Sheet piling .....lin. ft. | 200 | 29.00 | 185 | 5,365 | |
| Gates and guides, c.-i.....lbs. | 96,000 | .07 | 104,519 | 7,316 | |
| Stands and screw-stems comp.....each | 24 | 192.50[b] | 25 | 4,813 | |
| Flashboards .....each | 104 | 1.00 | 107 | 107 | |
| Pedestal supports (I-beams) .....lbs. | 10,000 | .07 | 4,800 | 336 | |
| Steel girder in intake.....lbs. | ..... | .07 | 10,388 | 727 | |
| Steel posts in intake.....lbs. | ..... | .07 | 17,592 | 1,231 | |
| Anchor bolts, etc.....lbs. | ..... | .07 | 2,200 | 154 | |
| Railroad rails for grillage.....ton | 17 | 60.00 | 20.19 | 1,211 | |
| Lumber for foot planks.....B. M. | 5,000 | 40.00 | ..... | ..... | |
| Lumber for temporary flume, etc., laid and calked..B. M. | 100,000 | 50.00 | 47,462 | 2,373 | |
| Lumber for boom .....B. M. | ..... | ..... | 4,824[c] | 241 | |
| Riprap .....cu. yds. | 500 | 4.00 | 3,387 | 13,548 | |
| Paving[d] .....sq. ft. | 4,000 | .15 | ..... | ..... | |
| Puddling .....cu. yds. | ..... | 2.00 | 840 | 1,680 | |
| | | | | | $72,432[e] |
| Canal and structures: | | | | | |
| Excavation Class 1.....cu. yds. | 661,000 | .23 | 676,533 | 155,603 | |
| Excavation, Class 2.....cu. yds. | ..... | .30 | 5,138 | 1,541 | |
| Excavation, Class 3.....cu. yds. | 3,800 | .40 | 40,000 | 16,000 | |
| Excavation, Class 4.....cu. yds. | 120,000 | .80 | 217,707 | 174,166 | |
| Concrete .....cu. yds. | 3,000 | 6.00 | 7,449 | 44,694 | |
| Cast-iron gates and guides.....lbs. | 84,000 | .07 | 34,178 | 2,392 | |
| Stands and screw-stems, complete.....each | 21 | 192.50[b] | 8 | 1,540 | |
| Flashboards .....each | 63 | 1.00 | 18 | 18 | |
| Steel girder in Pyramid Branch.....lbs. | 9,000 | .07 | 6,335 | 443 | |
| Steel posts in Pyramid Branch.....lbs. | ..... | .07 | 10,995 | 770 | |
| Anchor bolts, etc.....lbs. | ..... | .07 | 553 | 39 | |
| Railroad rails for reinforcing.....ton | ..... | 60.00 | 5.38 | 322 | |
| Wasteway gates, etc., set of 5, complete..... | ..... | ..... | ..... | 3,223[f] | |
| Riprap .....cu. yds. | ..... | 4.00 | 4,731 | 18,924 | |
| Puddling .....cu. yds. | 1,000 | 2.00 | 60 | 120 | |
| Total amount of bid, $324,967..... | | | | | |
| | | | | | $419,795 |
| Total contract cost ..... | | | | | $492,227 |
| U. S. material cost, 12,620 bbls. cement, at $2.55..... | | | | | 32,181 |
| U. S. engineer cost (survey, construction[g] and executive)[h], $27,288, less $4,629 charged to contractor | | | | | 22,659 |
| Grand total of Div. 1..... | | | | | $547,068 |

DIV. 2—7 miles—C. A. Warren & Co.

| | | | | | |
|---|---|---|---|---|---|
| Excavation Class 1.....cu. yds. | 737,000 | .23 | 668,306 | 153,710 | |
| Excavation, Class 2.....cu. yds. | ..... | .30 | 14,247 | 4,274 | |
| Excavation, Class 3.....cu. yds. | ..... | .40 | 18,919 | 7,568 | |
| Excavation, Class 4.....cu. yds. | 101,000 | .80 | 143,339 | 114,671 | |
| Tunneling, first method .....lin. ft. | 1,500 | 36.70 | 2,604.5 | 95,585 | |
| Tunneling, second method.....lin. ft. | 1,300 | 37.20 | 308.7 | 11,484 | |
| Extra lumber, Tunnel No. 3.....B. M. | ..... | 30.00 | 255,675 | 7,670 | |
| Extra lumber, Tunnel No. 1.....B. M. | ..... | 30.00 | 45,050 | 1,352 | |
| Extra concrete in tunnels.....cu. yds. | ..... | 12.00 | 381 | 4,572 | |
| Railroad rails in Tunnel No. 3.....tons | ..... | 60.00 | 9 | 540 | |
| Concrete .....cu. yds. | 10,000 | 5.50 | 11,280[i] | 61,930 | |
| Dry rubble wall[j] .....cu. yds. | ..... | 3.00 | 3,703 | 11,109 | |
| One highway bridge, complete..... | ..... | 1,500.00 | ..... | 1,500 | |
| Set of wastegates, complete..... | ..... | ..... | ..... | 3,482 | |
| Total amount of bid $415,020..... | | | | | |
| | | | | | $475,965 |
| Total contract cost..... | | | | | $479,447 |
| U. S. material cost, 20,036 bbls. cement, at $2.55..... | | | | | 51,092 |
| U. S. engineer cost, of construction solely, $12,148, less $858.45 charged to contractor..... | | | | | 11,290 |
| Grand total of Div. 2..... | | | | | $541,829 |

DIV. 3—17.9 miles—E. B. & A. L. Stone Co.

| | | | | | |
|---|---|---|---|---|---|
| Excavation Class 1.....cu. yds. | 831,000 | .20 | 795,714 | 159,142 | |
| Excavation, Class 2.....cu. yds. | 56,000 | .50 | 125,178 | 62,589 | |
| Excavation, Class 3.....cu. yds. | 19,000 | .75 | 24,912 | 18,684 | |
| Excavation, Class 4.....cu. yds. | 38,000 | 1.00 | 95,215 | 95,215 | |
| | | | | | $335,361 |
| Overhaul .....cu. yds. 100 ft | 100,000 | .02 | 174,470 | 3,489 | 3,489 |
| Total amount of bid, $250,700..... | | | | | |
| Total contract cost ..... | | | | | $339,120 |
| U. S. material cost, none..... | | | | | ..... |
| U. S. engineer, cost of construction solely..... | | | | | 8,281 |
| Terminal chute (temporary) ..... | | | | | 4,059 |
| Grand total of Div. 3..... | | | | | $351,460 |
| Total cost of Truckee Canal..... | | | | | $1,440,355 |

[a] Schedule quantities not strictly comparable with the actual quantities, owing to some classes of work in one list not being in the other, by reason of changes in design, etc. The total of bid is comparable with contract cost.

[b] $100 in regular bid, but this was for an entirely different design. The figure $192.50 was by special agreement. Separate payment for these items, which do not appear in regular estimates to contractor.

[c] 402 lin. ft. of 12 x 12 bought from contractor at regular contract price. This lumber to be used in making a boom above the dam to arrest floating logs, etc.

[d] All paving was classified as riprap, and paid for at price for such.

[e] Total cost of headworks is as follows:

| | |
|---|---|
| Contract cost alone ..... | $72,432 |
| 3,971 bbls. cement, at $2.55..... | 10,126 |
| One-eighth of engineer-cost of Div. 1..... | 2,832 |
| Total ..... | $85,390 |

[f] Includes first cost of gates and appliances, etc., and all handling and placing, plus 15%.

[g] Construction alone $18,009, by which engineer-cost can be compared with Div. 2.

[h] "Survey" ($2,673) includes the preliminary surveys for the canal made in 1902, and the location and other work in spring and summer of 1903 preceding construction; with rough assumption for the portion chargeable to this division. "Construction" ($18,009) includes all items of cost for the division engineer's force, from beginning work in September, 1903. "Executive" ($6,606) includes one-eighth of the cost of maintaining the central office of the project, at Reno or Hazen.

[i] 11,712 cu. yds. placed, but 452 disallowed contractor on account of his negligence and for doing unnecessary concreting.

[j] This material not in schedule for bids. Price made by agreement during construction.

FIG. 14. LOOKING NORTHERLY; HEADGATES OF SOUTH-SIDE CANAL IN FOREGROUND.

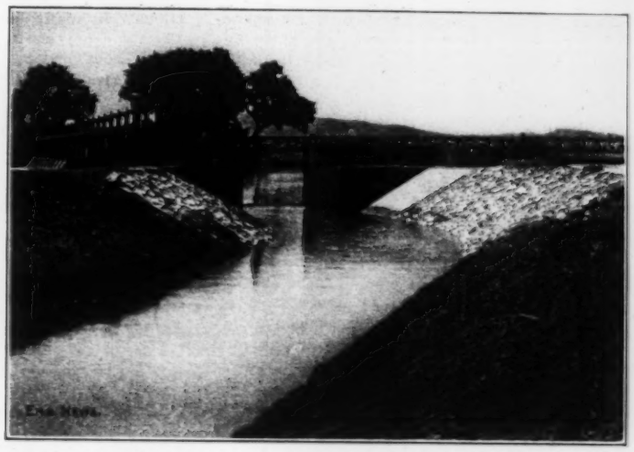


FIG. 15. LOOKING SOUTHERLY; HEADGATES OF NORTH-SIDE CANAL IN FOREGROUND.

FIGS. 14 AND 15. DIVERSION DAM ON CARSON RIVER AND HEADWORKS FOR MAIN DISTRIBUTING CANALS, TRUCKEE-CARSON IRRIGATION PROJECT.

with a worm-gear on the bronze socket or nut through which the stem passes. The gate is operated by a crank at either one or both ends of the shaft.

The stems are 2½-in., with threads on 1½-in. pitch—two threads per inch. Disregarding friction, the multiplication of actual power applied at the crank handle is about 1,200.

In all contract prices the stands, stems, shaft, etc., are included with the gates, which cost $810 each.

At the southside headgate the wall or sill is 5½ ft. higher than the floor of the dam. The down-stream side of the sill is of ogee shape, by which the water descends smoothly to the floor of the basin below, this being the grade of the canal and one foot higher than the grade of the dam. By the gates the crest can be made 5 ft. higher, so that practically all water up to a depth of 10½ ft. in front of the dam can be shut off. The screws of the gate stems are threaded for a depth of 9½-ft. lift.

TABLE II.—TOTAL COST TO CONTRACTOR AND TO UNITED STATES OF CONSTRUCTION OF DIVISION No. 2 OF MAIN TRUCKEE CANAL.

| Work or material. | Unit. | Unit contract price. | Quantity. | Contractor's unit cost. Materials. | Contractor's unit cost. Labor. | Contractor's total cost. | Contractor's amount earned. | U. S. material cost. | Total cost to U. S. | Unit cost to U. S. |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavation— | | | | | | | | | | |
| Class 1 | Cu yd. | $0.23 | 668,306 | ..... | $0.210 | $140,613 | $153,710 | ..... | $153,710 | $0.23 |
| " 2 | " | .30 | 14,247 | ..... | .532 | 7,581 | 4,274 | ..... | 4,274 | .30 |
| " 3 | " | .40 | 18,919 | ..... | .291 | 5,506 | 7,568 | ..... | 7,568 | .40 |
| " 4 | " | .80 | 143,339 | $0.065 | .851 | 131,338 | 114,671 | ..... | 114,671 | .80 |
| Concrete | " | 5.50 | 11,260[a] | ..... | 6.94[a] | 78,128 | 61,930 | $34,759 | 96,689 | 8.59 |
| Dry rubble wall | " | 3.00 | 3,703 | ..... | 1.982 | 7,339 | 11,109 | 311[b] | 11,420 | 3.09 |
| Tunnels— | | | | | | | | | | |
| 1st method | Lin. ft. | 36.70 | 2,604.5 | $33.41 sum | | 87,012 | 95,585 | 13,135 | 108,720 | 41.74 |
| 2nd " | " | 37.20 | 308.7 | 31.88 " | | 9,840 | 11,484 | 1,793 | 13,876 | 43.07 |
| Extra lumber in Tunnel No. 1 | M. B. M. | 30.00 | 45,050 | 17.00 | 8.00 | 1,126 | 1,352 | ..... | 1,352 | 30.00 |
| Extra lumber in Tunnel No. 3 | " | 30.00 | 255,675 | 17.00 | 8.00 | 6,392 | 7,670 | ..... | 7,670 | 30.00 |
| Extra concrete in tunnels— | | | | | | | | | | |
| 1st method | Cu. yd. | 12.00 | 301 | 6.618 sum | | 1,992 | 4,572 | 1,094 | 5,666 | 14.87 |
| 2nd " | " | 12.00 | 80 | 6.825 " | | 706 | | | | |
| Steel rails in Tunnel No. 3 | Ton | 60.00 | 9 | 60.00 " | | 540 | | | 540 | 60.00 |
| Highway bridge (Job) | | 1,500.00 | | 600.00 (Est.) | 909.50 | 1,510 | 1,500 | ..... | 1,500 | ..... |
| Set of waste-way gates— | | | | | | | | | | |
| First cost | | ..... | ..... | ..... | ..... | 2,542 | 2,542 | ..... | 2,542 | ..... |
| Labor, etc | | ..... | ..... | 8.37 | 478.07 | 486 | 486 | ..... | 486 | ..... |
| 15% sup'tg tools, etc. | | ..... | ..... | ..... | ..... | ..... | 454 | ..... | 454 | ..... |
| Engineering expense of construction solely | | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 12,148 | ..... |
| | | | | | | $482,652 | $479,447[c] | $51,092[d] | $542,687[c] | ..... |

[a] 11,712 cu. yds. were placed, and the amount of cement per cu. yd. is to be derived from this, but 452 cu. yds. were disallowed owing to unnecessary concreting and negligence on part of contractor. For 11,712 cu. yds. the contractor's unit cost is $6.65, and the U. S. cost for cement is $2.97 in place of $3.09.

[b] 122 bbls. of cement were used in certain parts of the rubble wall.

[c] This was decreased by $858 engineering expense charged to contractor, leaving U. S. net cost $541,829 and contractor's amount earned $478,589.

[d] All this for cement, there being 20,036 bbls., at $2.55. If the U. S. cost of inspection at the cement works be added the figure becomes $2.604.

TABLE IV.—COST DATA OF TUNNELS ON DIVISION 2, MAIN TRUCKEE CANAL.

| | Driving and timbering. | | | Concreting | | | Total contractor's cost. | |
|---|---|---|---|---|---|---|---|---|
| Tunnel No. | Length, ft. | Cost per lin. ft. | Total cost. | Cu. yds. | Cost per cu. yd. | Total cost. | Per lin. ft. | Total |
| 1 | 901 | $25.628 | $23,091 | 1,567 | $7.163 | $11,224 | $38.086 | $34,316 |
| 2 | 308.7 | 16.454 | 5,079 | 619 | 8.325 | 5,463 | 34.149 | 10.541 |
| 3 | 1,515 | 23.764 | 36,003 | 2,879 | 6.596 | 18,990 | 36.299 | 54,993 |
| 4 | 213.[a] | 26.02 | 5,542 | 320 | 6.918[b] | 2,214 | 36.414 | 7,756 |
| | 2,937.7 | $23.731 | $69,715 | 5,385 | $7.036 | $37,891 | $36.561 | $107,606 |

TABLE V.—CONTRACTOR'S COST AND EARNINGS ON TUNNELS ON DIVISION 2, MAIN TRUCKEE CANAL.

| | | | Contractor's amount earned. | | | | |
|---|---|---|---|---|---|---|---|
| Tunnel No. | Length, ft. | Contractor's total cost. | For specified section.[a] | Extra timbering. | Extra concrete. | Total. | Profit. |
| 1 | 901 | $34,316 | $33,067 | $1,352 | ..... | $34,418 | $102 |
| 2 | 308.7 | 10,542 | 11,484 | ..... | 960 | 12,444 | 1,902 |
| 3 | 1,515 | 54,993 | 55 601 | 7,670 | 3,900[b] | 67,171 | 12,178 |
| 4 | 188.5[c] | 7,756 | 6,918 | ..... | 252 | 7,170 | *..... |
| | $2,913.2 | $107,607 | $107,070 | $9,022 | 5.112 | $121,203 | $14,182 |
| | | | Net Profit | | | $13,596 | |
| | | | Per cent. profit (on cost) | | | 12.63 | |

* Loss on No. 4, $586.

[a] Figured at unit price per foot.

[b] $540 for 9 tons steel rails included in this.

[c] This includes straight tunneling and 1¼ times depth of shaft, the latter by special agreement.

[d] In this the depth of shaft was multiplied by 2, which is considered more correct in figuring, driving, etc.

The cost of the Carson diversion works was as follows:

| | |
|---|---|
| Total contract cost | $71,545 |
| Extra contract work (force account, etc.) | 2,184 |
| U. S. material cost, 3,115 bbls. cement, at $2.55. | 7,943 |
| Total | $81,672 |

The addition of the engineering cost (amount not kept) would probably bring the total to about the same as for the Truckee works, say $85,000.

SOUTHSIDE DISTRIBUTING CANALS.—The distributing canals have many features of novelty and interest, but space will permit mention of but a few.

The 26-ft. fall and the power-house foundation.—This combined structure is located on the main canal, 5.8 miles below the dam. As occasional drops have to be made in the canal grade to accommodate it to the general slope of the country, advantage is taken of the topography to concentrate a very heavy fall (26 ft.) at one place, and utilize it in the development of water power—the latter to be used in pumping water to a body of land above gravity flow. The development will not be made until some time in the future, but the foundations of the power-house were built in connection with the fall.

The arrangement consists of: (1) an enlargement of the canal section into a concrete lined forebay; (2) the fall itself, located in the center of the forebay, made semi-circular in plan so that the water pours over its four main openings in directions about radial, dropping into the

TABLE III.—EXCAVATION COSTS ON DIVISION No. 3.

| Contractors. | Class 1 | Class 2 | Class 3 | Class 4 |
|---|---|---|---|---|
| E. B. & A. L. Stone Co., | | | | |
| Cu. yds. exc... | 606,606 | 59,435 | 11,999 | 84,374 |
| Cost per cu. yd. | $0.249 | $0.273 | $0.433 | $0.850 |
| Total cost..... | $151,044 | $16,214 | $5,196 | 71,747 |
| J. W Beasley, Sub-contractor.[a] | | | | |
| Cu. yds. exc... | 112,465 | 51,774 | 4,601 | 4,002 |
| Cost per cu. yd. | $0.170 | $0.388 | $0.980 | $1.299 |
| Total cost..... | $19,122 | $20,024 | $4,510 | $5,201 |
| P. McD. Fuller, Sub-contractor.[b] | | | | |
| Cu. yds. exc... | 76,643 | 13,969 | 8,312 | 6,839 |
| Cost per cu. yd. | $0.220 | $0.509 | $0.306 | $1.025 |
| Total cost..... | $16.848 | $7,109 | $2,544 | $7,009 |

| | Total Excavation. | | | | |
|---|---|---|---|---|---|
| | Cost to contractor. | | | Cost to U. S. per contract. | |
| Class. | Cu. yds. excavation. | Cost per cu. yd. | Total cost. | Cost per cu. yd. | Total cost. |
| 1 | 795,714 | $0.235 | $187,014 | $0.20 | $159,143 |
| 2 | 125.178 | .346 | 43.347 | .50 | 62,589 |
| 3 | 24,912 | .492 | 12,250 | .75 | 18,684 |
| 4 | 95,215 | .882 | 83,957 | 1.00 | 95,215 |
| Totals, | 1,041,019 | $0.314 | $326,568,[c] | $0.325 | $335,631.[c] |

[a] Sub-contractor Beasley received (from head contractor) 12 cts., 30 cts., 40 cts. and 60 cts. for classes 1, 2, 3, 4, respectively.

[b] Sub-contractor Fuller received (from head contractor) 13 cts., 30 cts., 40 cts. and 60 cts. for classes 1, 2, 3, 4, respectively.

[c] 174,470 cu. yds. overhaul (100 ft.) at 2 cts., $3,489, included in cost to contractor but not to U. S. Total cost to contractor $326,569; to U. S., including overhaul, $339,120.

water cushion basin below; (3) the partly built walls of the upper end of the power-house, adjoining the fall; (4) the penstock openings, one on each side of the fall and leading from the forebay; (5) the foundations for the main part of the power-house, next downstream from the other parts. The total cost of the structure was $55,450.

Combined fall and wasteway.—This structure (Fig. 16) is 1¼ miles below the last one, and is for returning any desired portion of the canal flow back into the river, which is only about 900 ft. distant at this point. The arrangement includes: (1) a fall in the canal; (2) check-gates or stop-gates by which the water can be checked or entirely shut off; and (3) waste-gates by which any part or all of the water above this point can be discharged into a waste channel leading to the river. The drop in the canal is 2.61 ft.

The concrete structure is somewhat similar in general design to those used elsewhere on the canal. The gates are constructed similarly to those at the Carson dam, but the proportions are entirely different, the width being 6 ft., while the two gates together give a clear height of only 7 ft.

The stand used is also similar to the stands at the headgate of the canal, but the body is practically omitted, only the upper portion, containing the mechanism, being used. The gear is also the same, but it is driven by one continuous line of 1½-in. steel shafting, so that only two cranks (one at each end) are used. The set of check-gates and the one of waste-gates are placed at right angles to each other. Where they adjoin the line shaft for operating the waste-gates is produced past the end of the one for the check-gates. A bevel-gear wheel on the former engages one on the end of the latter, so that turning the waste-gate shaft lifts the waste-gates at the same time that it lowers the canal gates, or vice versa. A coupling is placed on the waste-gate shaft, close to this point, so that by disconnecting here each shaft can be operated independently.

OTHER STRUCTURES ON THE CANAL.—On the main canal are a number of drops or falls, one of which is shown by the view, Fig. 17. Substantial concrete and iron structures are provided for these. A number of laterals are taken out of the canal, and the lateral head gates were built at the same time as the canal. A check-gate is required in the canal at each one of these, and most of the drops are combined with lateral head-gates in order to reduce the number and expense of structures. In most of these combined structures a rising weir or weirs is used in the canal, to check the water properly.

Cost of main distributing canals.—The total cost of the northside and southside canals has been as follows:

| Part of system. | Principal schedule.[a] | Cost. |
|---|---|---|
| Headworks | B[b] | $81,672 |
| Canal excavation & embankments | A[c] | 261,273 |
| Canal structures | C[d] | 148,578 |
| Canal bridges | D | 5,991 |
| Total | | $497,514 |

[a]Showing under which contract the major portion of the work was done. Under Schedule "A" contract work was done applying to all parts of the system.
[b]Including $10,676 work under "A."
[c]Excluding $10,676 work under "A" applied at headworks.
[d]Including 26-ft. fall and power-house foundation, which was contracted for with the lateral ditch system and cost $55,450. Deducting this the total actual cost of the work contracted for, as per the bids opened July 15, 1904, becomes $442,064. This, of course, includes the U. S. direct expenses also.

### Lateral Distribution System.

The lateral system is for the subdivision and conveyance of the water in the main distributing canals to the land to be irrigated, including, in most cases, the delivery at the higher side of each farm unit. The work has been done partly by contract and partly by force account. It was started in November, 1904, and is still under way.

GENERAL PLAN.

From the main distributing canals are taken off the primary laterals, from these the secondary laterals, and from these in turn the tertiary laterals, which latter form the final subdivision and supply the individual farm units. This is the general arrangement, but there are variations. In many cases farm units are supplied directly from secondary laterals, and in some cases from primaries—usually only where the latter are much reduced in size.

The usual arrangement can be compared to a tree: the primary forming the trunk, the secondaries the main limbs and the tertiaries the smaller branches of these. Like the trunk, the primary reduces in size towards the end until it becomes a secondary or branches into two or more of the laterals, which in turn end in tertiaries. These secondaries also reduce in size towards the ends, similarly to the limbs.

The country reached is open, most of it nearly flat, and the general drainage is southeasterly. As far as possible all the laterals follow the

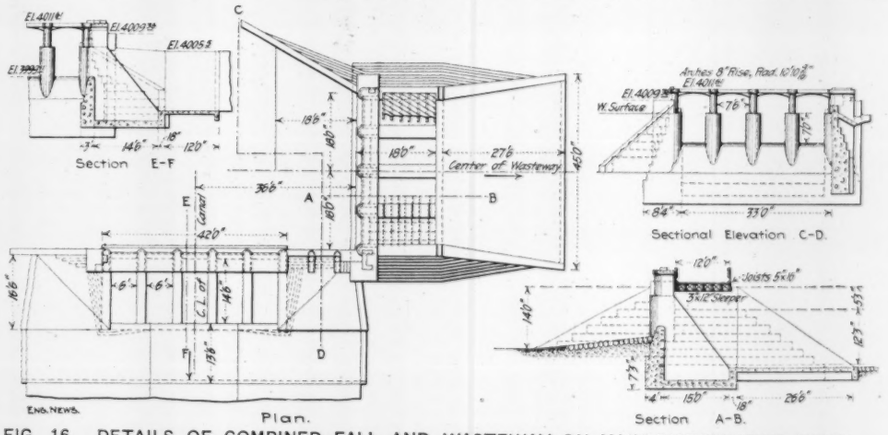



FIG. 16. DETAILS OF COMBINED FALL AND WASTEWAY ON MAIN DISTRIBUTING CANAL, TRUCKEE-CARSON IRRIGATION PROJECT.

higher ground, the primaries being located to follow the larger watershed lines and the others the subdivisions of a general drainage area. In most cases these lines, owing to the flatness of the country, are not well-defined, and it required some preliminary surveys as well as use of the topographic maps (which showed 5-ft. contours) to determine the best location.

Where the country is fairly uniform most of the ditches follow the land lines of the sectional subdivisions. In other localities, particularly for the laterals so far built under the northside main canal, this is impracticable. In the former case the secondaries and tertiaries are usually located along the higher side of the land subdivisions, by which the direct turning out of the water onto the lands is much facilitated.

DRAINS.

In connection with the laterals a system of drains was provided. These are to take care of seepage and drainage and waste water in general, including any surplus in the ditches that it may be desired to dispose of.

The advisability of drainage in connection with irrigation, particularly in a country like this (with comparatively little slope and a clay subsoil), is apparent. To one who has seen large areas of good land practically ruined by excessive irrigation and the entire lack of a drainage system, as has happened in numerous localities with the slipshod and wasteful methods so commonly used, the drainage feature is appreciated.

Where the land lines cannot be followed by the irrigation laterals, the drains follow the natural drainage lines, which are at the bottom of the depressions. They are intermediate between the laterals, the latter following the raised portions, which form what might be called very low ridges. The relation of the different parts of a system of drains is similar to that of the laterals, but with the flow reversed. The main drains south of the river discharge into Carson Lake or into one of the river branches or sloughs, while those for the northside system empty into Carson River or its "Old River" branch. Where the laterals follow the land lines the drains parallel them. The ditches are usually one-half mile apart, following the section and quarter-section lines. The laterals follow the upper side of the subdivisions and the drains the lower side, so that the lateral for one subdivision is paralleled just across the line (usually taken by a road) by a drain for the opposite piece of land.

The laterals are built so as to have normally part of the water section above the natural surface of the ground. With the drains the opposite condition is desired, and they are excavated much deeper. In them the side slopes forming the water section are 1½ to 1, while they are 2 to 1 in the laterals.

DESIGN OF LATERALS.

Side slopes next to water are 2 to 1; outside slopes of embankments, 1½ to 1. For the more recent work on the system the value of "n" has been assumed as .020. All the lines, even for the very smallest laterals, are staked out with the transit, regular curves being run in.

The structures used where the smaller laterals branch off from the larger ones are termed "turnouts." There are several types used, based mainly on the size, material and whether used with drops. The turnouts in the larger laterals are of concrete and in the smaller ones of wood. A lateral capacity of about 50 sec. ft. is usually the dividing line between the two different materials. As the general slope of the country is too excessive for continuous ditch grades, occasional falls or drops are put in, and advantage of these is taken in locating the turnouts so that in many cases of the latter they are combined with falls, thus reducing the number of structures. This is the case with practically all the concrete turnouts.

In all the lateral headgates, of whatever class or size, the gate openings are regulated by means of flash-boards, built-up gates not being used. In all the wooden structures California redwood is used, except for the flash-boards and foot-walks, for which Oregon pine is used. The much greater durability of the redwood, and its comparative freedom from shrinkage, make it decidedly the best where in contact with water or moist earth.

WORK EMBRACED BY THE LATERAL SYSTEM.—Besides the lateral ditches is included the improvement of the "Old River" branch of the Carson River, which is being done in order to make it carry the entire flow of the main river below where the latter has split into three branches, of which the above is one.

Up to Jan. 1, 1906, there had been constructed 242 miles of laterals, and 23 miles of river channel had been improved. The total cost was $429,053, of which the contract work cost $245,251 and the force account work $183,802. It has been found that the force account method is quite as economical for the Government as the contract work. By law a day's work on construction of the reclamation projects is limited to eight hours.

### Data of Actual Cost of Work on the Truckee-Carson Project.

On this work a system of cost-keeping records was begun at the start, by which, account could

be kept of all the details of cost to the contractor. The information secured was entered on record blanks, the latter being of a form more largely taken from those used on the New York Subway than any other works.

The final results derived from the records show fairly well the cost to the contractor of the different kinds of work, and what his direct profit or loss is. Table II. gives the total cost to the contractor and to the government of work on Div. 2 of the main Truckee Canal; Table III. gives cost to sub-contractors, to main contractor and to the United States of excavation on Div. 3; and Tables IV. and V. the cost figures of the tunnels on Div. 2 of the Truckee Canal.

**Status of Work on the Truckee-Carson Project.**

The beginning of the year 1906 found conditions about as follows: (1) The full project was 30% completed, based on cost. The full plan calls for reclamation of about 350,000 acres net at a cost of $9,000,000. (2) The first step in the project was 77% completed. This calls for the reclamation of 200,000 acres in Carson Sink Valley at a cost of $3,500,000. About $2,700,000 had already been spent, of which a considerable proportion was expense tending to develop *all* parts of the full project. The first step or development will cover 200,000 acres, of which it is estimated that only about 160,000 acres will be actually irrigated during any one season.

On the engineering staff employed on the construction of the Truckee-Carson project has been a large number of engineers and assistant engineers—too many for individual mention here notwithstanding the credit due them. All of the preliminary and the construction work has been in general charge of Mr. L. H. Taylor, Supervising Engineer of the Reclamation Service for Nevada. Mr. Taylor was also Hydrographer of the U. S. Geological Survey for a number of years preceding the organization of the Reclamation Service, and as such did much in securing the data for an early formulation of plans for the present project. Within less than a year after the passage of the Reclamation Act the first bids for construction were called for, and on June 17, 1905 (just three years after the passage of the Act), water was turned into the Truckee Canal. The project was the first to be started, and to be finished far enough to allow of settlement and irrigation, and may be properly called the pioneer project of the Reclamation Service.

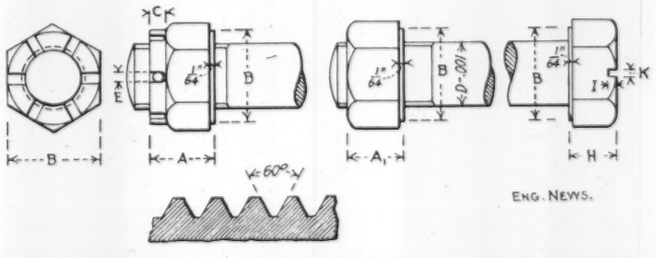
## NEW STANDARDS FOR SCREW THREADS AND BOLTS OF HIGH-GRADE STEEL.

New standards for bolts, screws and nuts have been established by the mechanical branch of the Association of Licensed Automobile Manufacturers. The United States standards for these parts were established by the United States Navy Department in May, 1868, and were generally used for all kinds of work until a few years ago, when the building of light machinery, especially for motor cars, necessitated a finer pitch for screw threads and smaller dimensions for bolt heads and nuts. The number and variety of the special threads and nuts made for this purpose had become so great as to cause in many cases considerable inconvenience and expense in the matter of renewals. The object of the new screw and nut standards is to overcome this condition, not only in the construction of motor cars, but in other light machinery where high-grade steel is used.

The representatives of many of the leading bolt manufacturers attended the meeting at which the new standards were evolved, and the specifications adopted are consistent with the practice and facilities of the manufacturers.

Tests were made of the nuts and heads before the standards were adopted, to make absolutely certain that the nuts and heads were large enough and that the threads would not strip. Tests were also made with ordinary material and with the material which is used for automobile work. In both cases the screw broke at the base of the thread inside the nut, as was desired. The material used for bolts in automobile work can be easily worked in automatic screw machines and is about twice as strong as ordinary bolt stock; it is also very much tougher, and shows a very fine fracture.

The accompanying drawings and the annexed table give in summarized form the details regarding the new standards for bolts and nuts. In the table all dimensions are in inches. All heads and nuts are to be semi-finish, and all bolts and nuts are to be made of steel, with a tensile strength of not less than 100,000 lbs. per sq. in., and an elastic limit not less than 60,000 lbs. per sq. in.




NEW STANDARDS FOR SCREW-THREADS AND BOLTS RECOMMENDED BY THE MECHANICAL BRANCH OF THE ASSOCIATION OF LICENSED AUTOMOBILE MANUFACTURERS.

B refers to all nuts and screw heads.
d = Diameter of cotter pin.
D × 1.5 = Length of threaded portion.
P = Pitch of thread.
P/8 = Flat top.

## SINGLE-PHASE EQUIPMENT FOR THE WASHINGTON, BALTIMORE & ANNAPOLIS RY.

One of the largest and most important installations of single-phase equipment for traction purposes is that to be used by the Washington, Baltimore & Annapolis Ry. for operating a 60-mile line between Washington and Baltimore with a branch line to Annapolis. Additional interest is centered in this installation by reason of its original promoters being the first to adopt the single-phase system for traction purposes.

About three years ago contracts were let for the construction of this line, but owing to financial difficulties the road was never built. The present contract differs considerably from the former one, calling for a higher trolley voltage, a higher frequency and motors of greater capacity. The trolley voltage is to be 6,600 volts, and the frequency 25 cycles per second. Nineteen express cars, capable of making 60 miles per hr., will be operated; also two work cars each sufficiently powerful to haul a train of five passenger coaches at 45 miles per hr. Each of these cars will be fitted with four General Electric 125-HP. motors, A. C.-D. C. motor equipments with the Sprague-General Electric train control. Four lower-power cars will be used for local service; these will run at 45 miles per hr., and be driven by two motors instead of four, but will be similarly controlled. The roadbed will be double-tracked throughout.

Power for the new road will be purchased from the Potomac Electric Co., at Washington, D. C., and will be delivered by that company at 6,600 volts three-phase to transformer substation No. 1. In order to obtain a balanced load on the three-phase generators, the current received at this substation will be changed from three-phase to two-phase by groups of two transformers connected three-phase on the 6,600-volt primary side and two-phase on the secondary side. Half of the transformers will have the secondaries wound for 6,600 volts, and the other half for 33,000 volts. The 6,600-volt windings will all be connected in parallel on the same phase, supplying single-phase current to the trolley up to substation No. 2. The 33,000-volt secondary windings will all be connected in multiple on the second phase, to the 33,000-volt transmission line, which will supply current to the step-down substation No. 2. Substation No. 1 will contain seven 800-KW. water-cooled transformers, three with 33,000-volt secondaries and four with 6,600-volt secondaries, one of the latter transformers forming a reserve. At substation No. 2 there will be four water-cooled transformers, 25 cycles, 800 KW., reducing the single-phase 33,000 volt current of the transmission line to 6,600-volt current suitable for delivery to the cars. These transformers will supply the Baltimore and the Annapolis sections of the line.

Substation No. 2 will be located adjacent to the car barns. For greater safety in inspecting and handling the cars, all of the trolley circuits in the car barn will be arranged for 600-volt direct-current, and for this purpose two 300-KW. motor-generator sets will be installed in this substation changing the 6,600-volt alternating current to 600 volts direct current. The motor end of these motor-generator sets will be connected direct to the trolley circuits, one phase being led from the trolley coming from substation No. 1, and the other from the transformers in substation No. 2. A feeder regulator will be placed in one phase so that the motor-generator sets will act as balancers, permitting the transformers in substation No. 2 connected on phase "B" to feed into the trolley line supplied by the substation No. 1 transformers on phase "A." In addition to acting as balancers and to supplying current to the cars in the barns, the motor-generator sets will also supply direct current to the motors in the repair shops located at this point.

Government regulations within the District of Columbia prohibit the use of the track return, so that within this section the cars will be operated with a double trolley. This portion of the tracks, as well as that within the city of Baltimore, is at present operated by direct current, and the new cars are designed to operate on direct current over these sections of the line.

The entire engineering work is in charge of the Roberts & Abbot Engineering Co., of Cleveland, Ohio, and contracts for the complete electrical equipment have been placed with the General Electric Co.

TABLE OF DIMENSIONS OF SCREWS AND NUTS ACCORDING TO THE NEW STANDARD.

| D | 1/4 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 7/8 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P | 28 | 24 | 24 | 20 | 20 | 18 | 18 | 16 | 16 | 14 | 14 |
| A | 9/32 | 21/64 | 13/32 | 29/64 | 9/16 | 32/64 | 23/32 | 42/64 | 13/16 | 29/32 | 1 |
| A1 | 7/32 | 17/64 | 21/64 | 3/8 | 7/16 | 31/64 | 35/64 | 19/32 | 21/32 | 42/64 | 7/8 |
| B | 3/8 | 1/2 | 9/16 | 11/16 | 3/4 | 7/8 | 15/16 | 1 | 1 1/8 | 1 1/4 | 1 7/16 |
| C | 3/32 | 3/32 | 1/8 | 1/8 | 3/16 | 3/16 | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 |
| E | 5/64 | 5/64 | 1/8 | 1/8 | 1/8 | 5/32 | 5/32 | 5/32 | 5/32 | 5/32 | 5/32 |
| H | 3/16 | 15/64 | 9/32 | 21/64 | 3/8 | 27/64 | 13/32 | 33/64 | 9/16 | 21/32 | 3/4 |
| I | 3/32 | 7/64 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 |
| K | 1/16 | 1/16 | 3/32 | 3/32 | 3/32 | 3/32 | 3/32 | 3/32 | 3/32 | 3/32 | 3/32 |
| d | 1/16 | 1/16 | 3/32 | 3/32 | 3/32 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 | 1/8 |

## THE DESIGN OF REINFORCED CONCRETE RETAINING WALLS.

By Edward Godfrey.*

The lateral pressure of earth is too uncertain to be defined by any law, and hence a correct theory for proportioning a retaining wall in the general sense of the term is not possible. Some earths will remain vertical for some time without any confining structure; some will even stand tunneling without caving in. A board fence will retain a considerable height of earth laid against it for a while. On the other hand, slips are liable to occur in earth after it has stood for some time unsupported. These often exert great force.

The lateral force of grain is, no doubt, nearly constant for a given kind of grain under given conditions. The same is probably true of sand, if one of the conditions be a definite proportion, or the entire absence, of moisture. But in the case of the substances generally classed under the term earth there is, as intimated, a variety of states, ranging from soft mud that will exert a lateral pressure approximating a fluid pressure, to shales that exert no active lateral pressure. A condition approximating a fluid pressure ought to be avoided in any good design by proper drainage. Two cases calling for special exercise of judgment are (1) the one mentioned, of shale, which is itself a sort of retaining wall of little durability, and (2) a case where large slips are probable, either due to an inclination of the underlying rock toward the retaining wall or to a heavy surcharge, that is, earth sloping steeply above the top of the wall.

This paper treats of a wall to retain ordinary fill or prevent natural earth from slipping. The most severe test of a retaining wall is usually the freezing and thawing of the earth around it. The forces produced thereby are quite indeterminate. They can, however, be largely diminished by drainage. It has been found that masonry walls having a base one-third the height of the earth retained will resist these forces and retain any ordinary earth with complete rigidity. That this relation between the base and height agrees with the theory of earth pressures commonly employed is shown by the following.

The theory referred to is based on deductions from the assumed action of a granular mass having no cohesion between its particles. It is found that the effect is that of a wedge of the material sliding without friction on a plane the slope of which bisects the angle of repose of the material and the vertical back of the retaining wall. It is customary in discussions on retaining walls to treat the force due to this wedge as though it were produced by a solid block with its center of pressure at a distance of one-third of h from the base. The calculations are simplified by treating it as a liquid pressure, the weight of the liquid per cubic foot being a certain fraction of the actual weight of the earth. This fraction is equal to the square of the tangent of the angle $\frac{a}{2}$ (Fig. 1), a being the complement of the angle of repose.

The angle of repose of ordinary earth is about 45°, half its complement is 22½°, and the square of the tangent of 22½° is .1716, or nearly one-sixth. Hence if we use the pressure of a liquid having a density one-sixth that of earth we will have the effect of this lateral pressure so far as horizontal forces are concerned. This will neglect the vertical component of the force of this sliding block. A small and uncertain amount of this vertical component would act in friction on the back of the wall; the remainder would be carried on the inclined surface upon which the block slides. As the force of friction tends to give greater stability to the wall, it is on the side of safety to neglect it.

Now from Fig. 1, if we take moments around X and use as the weight of earth 100 lbs. per cu. ft., and of masonry 150 lbs. per cu. ft., we have for stability the following equation of moments:

$$150\ h\ b \times \frac{b}{6} = \frac{100\ h}{6} \times \frac{h}{2} \times \frac{h}{3},$$

from which we find

$$h = 3\ b.$$

Hence, using only the horizontal forces and neglecting adhesion or friction on the back of the wall, we find that a wall having a height three times its base, which is usually considered in good proportion for a retaining wall, will be found to be stable against ordinary earth.

In retaining walls of reinforced concrete the earth itself may be utilized to prevent the overturning of the wall, not by its uncertain friction or adhesion but by its weight.

A form of reinforced concrete retaining wall coming into use is composed of a front curtain wall and a bottom slab, both reinforced with horizontal rods; wall and slab are united by ribs at intervals. Fig. 2 is a modification of that style of construction, by the addition of steps at the junction of the front wall and the bottom slab. The purpose of these steps will be made evident further on. The ribs are spaced a fixed

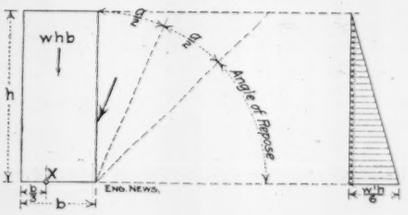



Fig. 1. Diagram of Earth Pressure Against a Retaining Wall with Vertical Face.

distance apart, the same for all heights of wall. The design is to be used only for walls having a base width of 5 ft. or more. The reason for the 5-ft. lower limit of base and for the constant spacing of ribs will be shown in a later paragraph.

In designs that have been illustrated in engineering publications, two sets of rods are shown in the bottom slab, one near the bottom of slab and the other near the top, both spaced uniformly for the full width. The writer believes this to be unnecessary and uneconomical. The execution of the work is greatly complicated thereby, and the forces are not present demanding this reinforcement. While it is true that this slab is continuous, and while somewhat less moment is found by considering it as continuous, the purposes of good construction are better served by proportioning the slab for the full moment as a simple beam and then adding some short rods in the top flange running across the support to relieve the concrete of tension.

The standard wall shown in Fig. 2 was evolved as a result of investigation to determine the proportions of a reinforced-concrete wall that would be stable against earth pressure on the same basis as a solid masonry wall, granting that the latter will be stable if made with a base one-third of its height. Three walls were taken, having bases 5, 10 and 15 ft. respectively, and heights 12, 24 and 36 ft. respectively, with other dimensions as given in Fig. 2. The volumes per bay were found to be 96.6, 452.8 and 1,168.5 cu. ft. respectively. Solid masonry walls of the same heights and having bases one-third the height would contain 3.73, 3.39 and 3.14 times as much in volume of masonry respectively as the concrete-steel walls; hence if reinforced concrete does not cost more than three or four times as much as solid masonry or plain concrete, the former is the more economical in the form of retaining walls. The additional excavation for the wider base may enter as a factor in the relative costs. It is not the purpose to give actual relative costs, but only to show that there is a large margin in favor of the reinforced-concrete retaining wall.

The centers of gravity of these three walls were found to be 1.43 ft., 3.00 ft. and 4.66 ft. respectively from the heel of wall. The respective volumes of earth over the slab are 332.3, 1,377.2 and 3,206.3 cu. ft. The centers of gravity of these volumes are located 2.96 ft., 5.97 ft. and 9.01 ft. respectively from the heel of wall. The moments of stability of these three walls, taken about a point one-third of the base from the heel, were found to be 39,599, 340,405 and 1,227,272 ft.-lbs. respectively, at 100 lbs. and 150 lbs. per cubic foot for earth and concrete respectively. The earth load considered is that directly over the bottom slab up to the level of the top of wall. Assuming that the force of the earth back of the wall is that of a liquid one-sixth of its density the weight of a cubic foot of earth to balance the above moments would be 110, 111 and 111 lbs. respectively.

One peculiarity respecting these three walls is that the resultant center of gravity of earth and concrete is in each case almost exactly in the center of the slab. This makes it proper to assume that the pressure due to the weight is uniformly distributed over the base, as shown at a, Fig. 2, as the stiffness of the bottom slab is sufficient to give this distribution. The reaction of the earth under the slab will be uniformly varying from zero intensity at the toe of wall to double the intensity of the uniform load at the heel of wall, as at b. The difference between these sets of forces, or the forces as shown at c, must be resisted by internal stresses in the concrete. On the left half of the bottom slab the forces are seen to be upward. If the construction were a reinforced slab, it would require the principal reinforcement in the upper part. For simplicity of construction it is desirable to avoid this. The close proximity of the vertical wall makes it possible to throw this force directly into that wall by means of the steps at the junction of wall and slab. These steps could of course be replaced by a chamfer or slope, if the latter were found to be simpler of construction.

On the right half of the bottom slab there is a vertical load downward varying in intensity from zero at middle to an amount at the edge of slab which may be taken as the weight of superimposed earth and of the slab itself. This is close to 250 × b lbs. per sq. ft. Taking the effective span of the slab as 7½ ft. the bending moment on the extreme right edge is 250 b × 7½ × 7½ ÷ 8 = 1,758 b. This is in foot-pounds per foot width of slab.

In order to give clearance for the angles shown in Fig. 2, the steel rods are placed one-sixth of the depth of slab from the bottom. Following the method employed by the writer, and described in Engineering News, March 15, 1906, the effective depth of the slab is found to be ⅔ of its depth. But as the depth of slab is $^{6}/_{10}$ b, its effective depth (that is, the distance from center of steel to center of compression in concrete) is $^{1}/_{10}$ b. For an area of steel = A, in sq. in. per foot width of slab, and a stress of 12,500 lbs. per sq. in. we have an allowed bending moment of 12,500 A × $^{1}/_{10}$ b = 1,250 A b foot-pounds.

Equating this to 1,758 b, found above, we have

$$A = 1.406.$$

This can be made up of four ⅝-in. diameter rods. It is thus seen that for any size of retaining wall ⅝-in. round rods spaced 3 ins. apart will take the tensile stress in the bottom slab at the extreme right edge.

When the area of steel does not exceed 1¼% of that of the concrete in the slab (see article above referred to) the stress on concrete will be within safe limits. It is seen that the area A found above is 1¼% of that of a slab 12 ins. wide and 9.4 ins. deep. For a base of 5 ft. the depth of slab is 9 ins.; hence a lower limit of about 5 ft. should be adhered to for this standard. For smaller walls the thickness of parts for a wall of 5-ft. base could be maintained and the span between ribs varied to suit the bending moment found. Thus, for a wall having 2½-ft. base (one-half of the standard 5-ft. wall), the load on the slab will be approximately one-half of that on the 5-ft. wall. (The height of this wall would be 6 ft.) A 9-in. slab

*Monongahela Bank Building, Pittsburg, Pa.

with the standard reinforcement will be good for a span $\sqrt{2}$ times the standard, or 10.6 ft., say 10 ft. clear.

The span of 7 ft. in the standard wall is found as follows: Let s = clear span in feet. The end shear on one foot of width of the slab is 250 b × ½ s = 125 b s. The shearing strength of a slab $^3/_{20}$ b feet deep and one foot wide, at 40 lbs. per sq. in. on the gross area is

$$^3/_{20}\ b \times 12 \times 12 \times 40 = 864\ b.$$

Then from the equation

$$125\ b\ s = 864\ b,$$

we find s = 6.91 ft.

Since this remains true for all sizes of standard walls, it is seen that the shear is taken care of also in walls of less than 5 ft. in base, as the slabs will have a greater relative depth than in the standard walls.

The reinforcement in front wall is found as follows: It will be seen in the standard retaining wall that the depth from top of wall to top of steps is 1.9 b. The intensity of horizontal pressure is therefore 1.9 b × ⅓ × 100 lbs. per sq. ft. This gives a moment on a foot depth of wall = 223 b ft.-lbs. The moment of resistance of the concrete-steel slab, found as above, is

$$12{,}500\ A \times \frac{2}{3} \times \frac{b}{10} = 833\ A\ b.$$

From

$$223\ b = 833\ A\ b,$$

we have $A = .267$ sq. in.

This would be made up by one ⅝-in. round rod for every foot of depth of wall. This reinforcement is carried up to the top of the wall and is used as indicated on the lower portion of the wall and on the bottom, though theoretically less reinforcement would be quired. The purpose is to tie the wall together.

The rods in the rib act to tie together the bottom slab and the vertical wall, the manifest tendency being for these to pull against each other. The chief use of the concrete in the ribs is to protect these rods. It is essential that the rods have an efficient end anchorage, and any other anchorage or bond can serve only a subsidiary purpose. The line of cleavage in the rib may be immediately above the bottom slab, and practically the whole strength of the rod is needed at that plane. In the short depth of the slab there is not length enough for even mechanical bond to take effective hold for the full strength of the rods. Hooks or curves on the ends of rods have not been shown by tests to be effective end anchorages. Such a detail would not be accepted in structural steel work. The use of plain round rods with thread and nut at end, attached to a front-to-back angle in the bottom of the slab, as shown in Fig. 2, seems to be the most economical as well as the most effective means of meeting these conditions. These angles may also act as anchors for the horizontal rods, at ends of wall, if any such anchorage is needed.

The angles serve to locate the rods properly and to hold them in position against displacement during the placing of the concrete. They also make it more difficult to omit any rods and easy to detect any omissions. All of these points are of great weight in construction where unskilled labor is so commonly employed.

The rods in the rib take the downward force shown at c, Fig. 2, the amount of which at the right edge is at a rate per foot close to 250 b × 7 = 1,750 b lbs. On a retaining wall of 5-ft. base the load in a foot is 8,750 lbs. At 12,500 lbs. per sq. in. this would require four rods ½-in. in diameter. For a 10-ft. base four 11-16-in. round rods are required, etc. By giving these rods the same horizontal spacing at bottom as those in the bottom slab and varying the rate of spacing in the same manner, the vertical load is taken care of.

These rods start vertical; hence the vertical load measures their stress and not the component in a diagonal direction. Their stress is not uniform throughout, but they begin near the foot of the wall to transmit their stress into the concrete to resist the upward thrust of the forces on the left half of the base. Their radius of curvature should not be less than about twenty times their diameter, so that the unit pressure exerted by the side of rod on the concrete will not exceed safe limits. (A square rod curved to a radius twenty times its diameter will exert a radial force on its side one-twentieth of the intensity of its tension, which is the usual ratio between the allowable stresses in steel and concrete. The use of sharp bends in embedded rods is a structural fault often met with.)

The rods should have two nuts on the ends, so that the end nut can be drawn to a tight bearing on the angle. Horizontal rods should be spliced by sleeve nuts.

A modification of the design can be made in which the rods in rib pass through slotted (or large sized punched) holes, and have cast iron beveled washers. The rods can then be straight. The inclination would be such as to give about 8% more stress than found in vertical rods.

The gripping of concrete is sufficient to make up for the difference in strength of rod at root of thread and that of the full section.

Anchors that take the full stress of rods should have their areas twenty times the section of the rod. This condition would govern the size of the flange of angle to which rods in the rib connect. These angles could vary from about 2½ × 2½ × 5-16-in. for small-sized walls to 4 × 3 × ⅝-in. for large walls.

The formulas ordinarily given for continuous beams are for beams having a uniform moment of inertia. If the beams have not a uniform moment of inertia, the formula does not hold. If a beam be purposely designed so as not to have a uniform moment of inertia, it will deflect more at the section not reinforced for the full moment, and thus put greater moment on the fully reinforced section. This is the basis for the somewhat arbitrary reinforcement of the upper part of bottom slabs. The bending moment at the middle of this slab cannot exceed that for a simple span. The upper rods are added to prevent cracking, and consequent weakening of the slab in shear, near the ribs.

It is recommended that long walls be concreted from one end to the other, and not uniformly from the ground up; so that the shrinking of the concrete as it sets will not act on the whole length of the wall at once. It is also recommended that at expansion joints, say about every 100 to 150 ft., a complete separation be made in the wall, with an end rib in each portion of the wall.

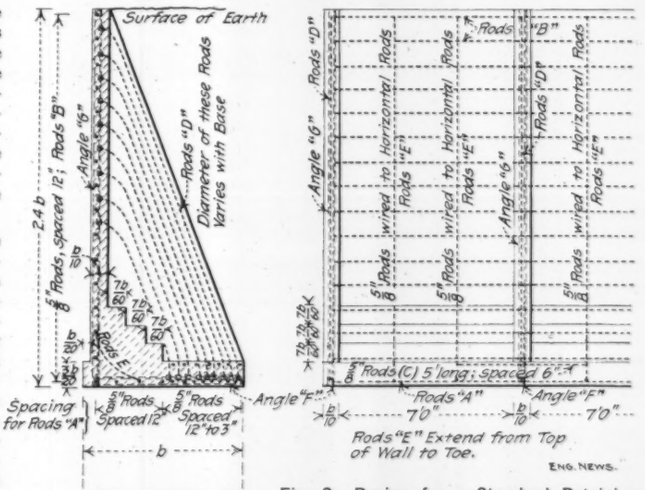



Fig. 2. Design for a Standard Retaining Wall of Reinforced Concrete, for any Base not Less than 5 Ft.

(Dimensions of parts are given in terms of width of base. Steel stress, 12,500 lbs. per sq. in. Beam reinforcement not to exceed 1¼%.)

## A PLEA FOR BETTER BUILDING LAWS.

An address on the general subject named above was delivered before the annual meeting of the International Association of Fire Engineers, held at Dallas, Tex., Oct. 9-12, 1906. The address was made by Mr. C. G. Smith, Secretary of the German-American Insurance Co., who attended the meeting as a delegate from the National Board of Fire Underwriters. After discussing in a general way the necessity for building laws, Mr. Smith stated:

> There is a comprehensive way of drafting a building code and there is a superficial way. A building code must be elastic enough to provide for the largest as well as the smallest structure. Its requirements should be expressed clearly and concisely, using simple words and avoiding obstruse terms and phrases. With the exception of a few sections that have to do with complicated construction, as, for example, rules for determining the strength of metal columns, there is no reason why language should not be used that is perfectly intelligible to the average builder, architect, fire engineer and owner. The code should contain no intricacies and require only what is really necessary for public safety. Its provisions must, of course, be general in their application; and, fortunately, past experience has proven unerringly what may be accurately stated as safe and good in the essential features of such ordinary buildings as comprise nine-tenths of the whole number. A building code does not mean that a citizen shall not be left as free as is consistent with safety to select materials and appliances suitable to his purpose, but the interests, or supposed interests, of individuals should always yield to the public good. The wisdom of this cannot be questioned.

Following the remarks just given, reference was made to the defects in existing building codes and the lack of "uniformity in text or in arrangement" between the codes of various cities. The evolution of "a uniform building code applicable to all cities, large and small," by a committee of the National Board of Fire Underwriters, was briefly outlined by Mr. Smith. In support of the proposition that better building laws are needed, the author of the paper stated that the normal fire loss in a single year in this country is over $173,000,000, a very large percentage of which might be prevented "by the adoption of improved methods for the construction of buildings and the application of increased facilities for extinguishing fires." The loss above stated, on a basis of 85,000,000 population, is more than $2 per year per capita, as compared with 33 cts. in six European countries.

In conclusion the author called attention to the popular esteem in which fire chiefs are held in practically all the cities in the country, and suggested that the fire department officials assembled at the meeting use their influence in their respective cities to secure the adoption of better building codes.

SCARCITY OF LABOR IN THE COPPER MINES has cut down the production of this metal to such an extent that a copper famine seems imminent. In every mining district of the West skilled miners are at a premium, and the lack of ordinary laborers, coupled with the urgent demands from manufacturers of electrical machinery and appliances, have created an unprecedented state of affairs. Throughout the country there is a general complaint of inability to obtain electrical machinery, although it is reported that the United Metals Selling Co. sold within the last month over 100,000,000 lbs. of copper, breaking all records in the history of the company. That the consumption of copper is much above the production is apparent, and there appears to be no indication of a change in the situation, owing to the scarcity of labor.

## THE FORM OF CONTRACT FOR THE COMPLETION OF THE PANAMA CANAL, ON WHICH BIDS ARE TO BE RECEIVED DEC. 12.

The contract for completing the Panama Canal was received last week just as we were going to press, preventing us from giving more than a brief synopsis of its contents. On our editorial page this week we have given an analysis of the principal features of the contract, and below we print it practically in full.

Under this contract the contractor is to be paid the entire cost of doing the work, be it more or less, including all his expense for foremen, superintendence, and clerical labor. His profit is to be the percentage on this cost which he bids plus premiums for building it in less time and for less money than the estimates or minus penalties for taking more time and expending more than the estimated cost; further, the contractor can appoint two out of the five members of the board which fixes these estimates.

Apart from its interest as being the contract for the greatest piece of engineering work ever undertaken, the novel form of the contract and the fact that it relieves the contractor from risk and yet gives him a great incentive to rapid and economical work, so far as both are compatible with high-class construction, makes it worth the very careful study of every engineer and contractor.

### Form of Contract.

ARTICLE I.—WORK TO BE DONE BY THE CONTRACTOR.

The work to be done by the contractor shall be construction work proper, and shall consist of the following items:

1. Dredging, clearing and excavating canal from the locks at either end of the canal to deep water.
2. Construction of the proposed dam at Gatun, and of the dam or dams at or near the southern or Pacific end of the canal.
3. Construction of all locks and regulating works at either end of the canal and wherever located.
4. Dredging, clearing and excavating canal from the dams at either end to the Culebra Cut.
5. Excavation and completion of the Culebra Cut and revetments and the approaches thereto.
6. Removal and reconstruction of the Panama Railroad upon lines of relocation to be fixed by chief engineer of the commission.
7. Removal and transportation of all spoil of whatsoever character, whether by land or water, to such points or places, and the disposition thereof in such manner, as may be designated by the said chief engineer.
8. The quarrying, transportation and dressing of all stone required for masonry work, the manufacture and transportation on the isthmus of concrete, the transportation and preparation on the isthmus of timber, or other materials, except finished metallic parts, used in the proper execution of the above work and constituting a part of the completed structure and the appliances adjunct thereto and necessary to the proper maintenance and operation thereof.
9. All work herein required to be done shall be performed according to the plans and specifications furnished by the chief engineer of the commission; but said plans and specifications will be subject at any time to such alterations and changes as may be deemed advisable by the chief engineer or the commission.

ARTICLE II.—EXTRA WORK.

Should the commission, prior to the completion of the canal, decide to construct breakwaters at either end of the canal, additional reservoirs or dams, or additional auxiliary works of any character not now definitely decided upon, the same shall be constructed by the contractor upon the terms upon which he agrees hereunder to perform the work upon the canal proper; but a supplemental estimate of the cost and time for the completion of the said additional works shall be made by an engineering committee, such as is hereinafter provided for, in the same manner as the estimate is provided to be made by the original engineering committee of the cost and time required for the construction of the canal proper.

ARTICLE III.—PLANT AND FACILITIES FURNISHED BY THE COMMISSION.

The commission agrees to furnish, free of cost to the contractor, plant, facilities and means as follows:

1. All locomotives, cars, steam shovels, drills, cranes, dredges, tugs, scows, dumps, rails, ties and track materials, electric light or power plants, and other machinery of a substantial character required to efficiently carry on the construction work; but not hand tools nor machinery of a minor character usually carried in stock, save through its Department of Materials and Supplies as hereinafter provided.
2. All raw materials put into the work, the machinery and appliances necessary for the operation and protection of the locks or other parts of the canal, but not the treatment, shaping, finishing, transportation upon the isthmus, or incorporation into the work of such materials, nor the erection, or assembling of such machinery upon the isthmus; cement; explosives; oil, coal, fuel, and at the election of the commission, electricity, for the proper operation of any rolling or floating stock or other machinery used by the contractor in the performance of his work upon the isthmus: Provided, however, that the commission may, in its discretion, transfer to the contractor the manufacture of cement or explosives, if it should be found that either can be properly made upon the isthmus, and the manufacture upon the isthmus of metallic parts of the locks and auxiliary works of the canal, the cost of such manufacture to be added in such case to the total estimated cost of the canal as hereinafter provided to be arrived at.
3. Construction tracks already built in a condition not less efficient than now existing; but additional construction tracks, including the relocation of those turned over to the contractor, must be built by the contractor.
4. Quarters for the proper housing of all necessary employees of the contractor, but the commission shall be allowed reasonable time for the construction of quarters additional to those now existing.
5. Warehouses for the storage of the contractor's tools and supplies.
6. Hospitals and hospital service for sick employees of the contractor.
7. Office buildings for the accommodation of the contractor's clerical and administrative force actually employed upon the isthmus in connection with the construction of the Canal.
8. Transportation of the contractor's employees, employees' families, and supplies over the Panama Railroad and its steamship lines at rates not greater than one-half the regular published tariff rates. The contractor shall also be at liberty in all cases, where the transportation facilities afforded by the Panama Railroad steamship line are not sufficient for the needs of the contractor's business, to employ such other lines of transportation as he sees fit, until such time as the Panama Railroad steamship line is in condition to resume or furnish sufficient service to the contractor.
9. Free telegraph and telephone service upon the isthmus necessary to the actual efficient discharge of the contractor's business.
10. Free trackage rights over the Panama Railroad Company's tracks for the work trains of the contractor, from canal cuttings to dump grounds, or docks when necessary, and return; and as a part of this obligation, the commission will assume the cost of constructing such additional trackage, yards, or other facilities of the Panama Railroad as may be essential to the proper execution by the contractor of the work herein provided for, the amount and character of such work being always subject to the direction and approval of the chief engineer of the commission.
11. Water for offices, engines, shovels, drills, dredges, and other equipment needing water, from the water mains and tanks of the commission.
12. Commissary stores which will be open to the contractor and his employees upon the same terms as to the commission's own employees. The commission will also supply from its other departments, so far as it may have the same available, tools and supplies which it is not the duty of the commission to furnish free hereunder upon the terms of cost plus the usual handling charges.
13. Mess-house privileges for contractor's employees equal to those at any time extended to the employees of the commission. The contractor shall also have the privilege of taking over and operating upon his own account such mess houses, either directly or by contract with a third party, subject in all cases to the direction and approval of the chief engineer with respect to prices, privileges and general methods, and subject to the duty to furnish to the commission's employees accommodations in all respects equal to those furnished to the contractor's own employees. Mess or lodging houses furnished by the commission to the contractor, or any subcontractor, shall be subject to daily inspection by the chief engineer or his agents, and all directions and modifications which the chief engineer may deem necessary for the proper housing and feeding of such employees, shall at once be carried into effect by the contractor. Any profit or loss arising from the operation by the contractor of mess houses, shall be debited against or credited to the contractor.
14. The equipment which the commission under this article agrees to supply it will also maintain; and it will to that end operate and properly furnish and supply such machine and other shops as may be necessary, but this obligation shall not extend to the making of repairs which are ordinarily known as outside, yard or running repairs, which must be made by the contractor.
15. The commission, to the extent to which its machine shops may be adequate, will manufacture or repair for the contractor such minor machinery and tools as can be economically and conveniently manufactured or repaired at the said shops, charging the contractor therefor actual cost plus fifteen per cent.
16. The judgment of the chief engineer of the commission shall in all cases be controlling as to the extent and character of the facilities to be supplied by the commission under this article.

ARTICLE IV.—FUNCTIONS RESERVED TO THE COMMISSION.

The commission will retain control of:

1. All engineering work in connection with the construction of the canal, including surveys and the general direction and control of the construction work to be done by the contractor with the right to fully inspect same.
2. Municipal engineering, including the construction of water-works, sewers, roads and streets wherever located.
3. The Governmental and Police Department.
4. The Sanitary and Hospital Department.
5. The Commissary Department.
6. Mess houses, except in so far as the same may be taken over by the contractor as hereinbefore provided for, and the inspection of the same in that event.
7. Quarters.
8. The construction and maintenance of buildings.
9. The operation of the Panama Railroad.
10. An Auditing Department, which shall have control over the books and accounts of the contractor, with authority to direct the manner in which all accounts relating to expenditure upon the canal construction by the contractor shall be kept and to which department the books and accounts of the contractor shall at all times be open.
11. A department of materials and supplies.
12. And generally, all powers, rights and privileges not herein specifically ceded to the contractor.

ARTICLE V.—TO BE SUPPLIED BY THE CONTRACTOR.

1. The contractor shall furnish and employ all labor, foremen, superintendents, clerks, general office staff, and furnish all tools and machinery of a minor character necessary to efficiently operate the plant and carry out the work to be undertaken hereunder.
2. He shall make all repairs commonly known as outside repairs upon equipment and machinery employed by him.

ARTICLE VI.—OBLIGATIONS TO BE ASSUMED BY CONTRACTOR.

1. The contractor shall begin the actual work of construction within sixty days from the signing of this contract.
2. He shall take over into his own employment all employees on the isthmus upon the pay-rolls of the commission at the time that he begins work, except such employees as the commission may reserve to its own use. Employees on what is known as the "gold list" taken over by the contractor under this article shall not be discharged, nor shall their salaries be reduced, except for cause, and then only when their discharge or salary reduction is approved of by the chief engineer of the commission.
3. He shall assume and carry out all contracts that may have been entered into by the commission for the supply and employment of foreign or other labor, and shall execute in connection therewith such agreements or papers as may be required by the commission.
4. He shall scrupulously abide by all the rules and regulations that may be put into force from time to time by the sanitary department of the commission, and shall issue all orders required of him by the commission for the proper observance and enforcement of said rules and regulations.
5. He shall, on written notice from the chairman or chief engineer of the commission, discharge for cause any employee who may be in his service.
6. He shall comply with all laws of Congress or of the Government of the Canal Zone, with respect to the hours of labor, character of employees, and other matters in so far as the same may be applicable in the work undertaken by him; and all provisions of law bearing upon the performance by the contractor of this contract shall be regarded as incorporated into, and made a part hereof whether expressed or not.
7. He shall perform all work embraced in this contract in the most thorough and workmanlike manner, and subject to the approval of the chief engineer of the commission, with the highest regard for the safety of life and property, and in accordance with the plans, specifications, and drawings furnished by the chief engineer of the commission, and subject to his orders and directions.
8. No material shall be put into the work by the contractor of which the chief engineer may disapprove; but failure by the chief engineer to disapprove of unsound materials or the improper preparation or use of material shall not exempt the contractor from liability to the

commission for damage or extra expenditure occasioned thereby.

9. He shall carry on the construction work, if required, during the night as well as during the day, and in such shifts as the chief engineer shall direct.

10. He shall assume and be responsible for all just legal claims for injuries or wrongs inflicted upon persons and property by his own act or that of any of his employees, except property and land damages necessarily occasioned by the orderly construction of the canal and auxiliary works.

11. He shall not assign or transfer this contract or any interest therein without the written consent of the commission.

12. He shall not enter into subcontracts for the performance of the work to be undertaken hereunder, without the written consent of the commission; and, as a condition precedent to seeking the consent of the commission, shall furnish the commission with a written statement as to the nature of the proposed subcontract and the leading provisions thereof, and with detailed information concerning the proposed subcontractor or subcontractors, their financial standing and resources, their facilities for prosecuting the work of canal construction, and such other information as may be required of him with respect to them or any of them.

13. In all cases where subcontracts are entered into with the approval of the commission, and bonds are taken by the contractor to secure the performance of such subcontracts, such bonds shall be taken subject to assignment to the commission, and shall be so assigned, as additional security for the performance by the contractor and subcontractor of this contract.

14. He shall maintain upon the isthmus an agent upon whom all notices required or proper to be served hereunder upon either himself, his sureties, or any subcontractor, may be served, and who shall, in addition, be authorized to accept service of legal process on behalf of himself, his sureties, or any subcontractor at the suit of the commission or any private person.

15. He shall be responsible to the commission for all injuries or damages inflicted upon the plant with which he may be intrusted by the commission, or upon the canal or any of its auxiliary works by reason of his own negligence or error of judgment, or the negligence or error of judgment of any of his employees or subcontractors, or the employees of such subcontractors; but shall not be responsible for any depreciation in the value of the plant or material intrusted to him or any of his subcontractors or employees by the commission, attributable to ordinary wear and tear. Damages inflicted under this clause shall be estimated by the chief engineer, subject only to revision by the chairman of the commission, and the same shall be deducted from the percentage earned by the contractor under this contract, if any, or if no percentage shall have been earned, the said damages shall be paid by the contractor or his surety.

ARTICLE VII.—PAYMENTS.

1. Payments will be made to the contractor by the commission on or about the fifteenth day of each month in current coin of the United States or its equivalent, either in Panama, Washington or New York City, as the contractor may elect, covering the cost of the actual construction work done by the contractor or his subcontractors upon the canal during the preceding calendar month, including therein labor cost, superintendence and clerical service on the isthmus, transportation of workmen to the isthmus, overtime paid to employees, wages paid to employees when sick, if allowed by the chief engineer, current purchases of tools and repairs made by the contractor, and the actual cost to the contractor of any materials put into the work; and excluding the cost of organization, administration, legal and general expenses of the contractor, interest, taxes, cable service, commissary purchases and the cost of running the mess houses, should the contractor take over the same, and all expenses to which he shall have been put by reason of his own negligence or inefficiency, or by reason of the supply of any unsound or imperfect materials rejected by the chief engineer or any imperfect preparation or use of material, and all expenses not directly connected with the construction work which he may have incurred on his own account. Where subcontractors are employed by the contractor upon a percentage basis, only such payments will be made to the contractor on account of such subcontractors as would be made in the event the contractor had done the work directly.

2. Payments will be made upon certificates signed by some designated official of the contractor upon the isthmus, and the chief engineer of the commission, accompanied by vouchers showing in detail such expenditures as are authorized under this article.

ARTICLE VIII.—FINAL COMPENSATION.

Upon the completion of the construction work upon the canal proper, and the final acceptance by the chief engineer or the commission of the work done by the contractor, there will be paid to the contractor ——— per centum upon the total estimated cost of construction as fixed by the engineering committee under Article IX. hereof, subject to the following conditions:

1. If the total actual cost of the construction estimated upon the basis prescribed in Article VII. shall exceed the total estimated cost of construction as fixed by the engineering committee as hereinafter provided, there shall be deducted one-half per centum from the per centum otherwise payable to the contractor for each five million dollars, or half fractional part thereof, by which the actual cost shall exceed the estimated cost. If the actual cost shall fall below the estimated cost, the contractor shall receive in addition to the stipulated percentage upon the estimate of the engineering committee one-third of the difference between such actual cost and the estimatd cost. In no even shall the contractor receive a percentage upon any part of the actual cost exceeding the estimated cost, unless the estimated cost be increased, as herein provided.

2. If the construction work upon the canal proper herein provided for shall not be completed by the contractor within the time fixed by the engineering committee, the contractor shall forfeit as liquidated damages for each month that the work of construction shall exceed the estimated time for the construction $100,000; if it shall be completed by him in less time, he shall be paid a premium of $100,000, in addition to all other compensation earned hereunder, for each month less than the estimated time in which he shall have completed it.

3. If, however, at the end of any year of the contractor's work, the cost of construction has not exceeded nor the rate fallen below the proportionate estimated cost or rate of construction, the commission will pay to the contractor two-thirds of the agreed percentage upon the actual cost to such date; but if at any subsequent time the cost should exceed or the rate fall below the proper proportionate cost or rate, no further portion of the agreed percentage shall be paid until the arrears of cost and rate are made up.

4. No allowance shall be made the contractor for any interruption or suspension of the work hereunder, unless the same shall be due to an act of God or a public enemy, or an order of the commission, or failure of the commission to maintain or furnish such plant or materials as it agrees hereunder to maintain or furnish. Where the suspension of work is due to any of the last-mentioned causes, the time of suspension or interruption shall be added to the estimated time for the construction of the canal.

5. If any suspension of the work should be due to a default or order of the commission, and such suspension should exceed one year, the contract may be treated as terminated by the contractor, who shall thereupon become entitled to receive such percentage as he may have earned upon the work actually done. At such time also an estimate shall be made by the chief engineer to ascertain whether the work to such time has proportionately exceeded or fallen behind the estimated cost and time; and proportionate profits or deductions shall be credited to or charged against the contractor accordingly.

6. All questions with reference to the percentage earned by the contractor hereunder, the deductions therefrom, or premiums thereon, or the increase of the estimated period of construction, attributable to the above-named causes, shall be determined by the chief engineer of the commission, subject only to appeal to the chairman of the commission.

ARTICLE IX.—METHOD OF ESTIMATING COST AND TIME OF CONSTRUCTION OF CANAL.

1. Within ten days from the execution of this contract, the contractor shall nominate two engineers of approved standing, who, together with three engineers to be nominated by the Commission within the same period of time, shall constitute an engineering committee. One of the three engineers nominated by the commission shall be the chief engineer of the commission, who shall be the chairman of the engineering committee. The said engineering committee thereupon, upon a consideration of all available data, and, if in their judgment it be deemed expedient, upon personal investigation of the work to be performed upon the isthmus and of the conditions surrounding the same, shall estimate the total reasonable cost of completing the construction of the canal as herein outlined, and as may be more particularly defined in the plans and specifications for the construction of the canal submitted to said committee by the commission. In arriving at the said estimated reasonable cost, the committee shall carefully take into account all the services to be performed and the means, facilities and materials to be supplied by the commission in the construction of the said canal, as hereinabove provided for, and shall exclude from the estimated cost the value of same and all interest charges of whatsoever character, cost of right-of-way and land damages, and all expenses incurred by the commission in discharging the portion of the work reserved to it, and the organization, administration, legal, general and other expenses of the contractor as defined in Article VII., and shall make no allowance for losses or damages, legal or otherwise, attributable to the acts of himself or employees and subject to be sustained by him, nor any allowance for contingencies.

2. The engineering committee shall likewise, from similar data and investigations, estimate the reasonable time for the construction of the canal with the facilities afforded to the contractor under the terms of this contract. In fixing the said time, they shall assume that the contractor will at all times employ, on a basis of eight hours a day for American labor and ten hours a day for foreign labor, a force of laborers and employees upon the actual work of construction or the superintendence thereof equal to the number that can be efficiently employed, having due regard to the progressive condition of the work, and that he will be supplied by the commission with the plant hereinbefore described necessary to fully employ his working forces.

3. The committee shall also submit alternative estimates of time and cost, based upon night work and two shifts a day of ten hours each for foreign and eight hours for American labor, and also upon continuous work with three shifts a day of eight hours each, and shall formulate a rule by which these estimates may be increased, or diminished, according to the time that the work may be carried on upon one or the other of these several bases.

4. If, at any future time, the plans and specifications for the construction of the canal, as submitted to the said engineering committee, shall be materially altered in any respect, the said committee, or a new committee formed in the same manner as the original committee, shall, upon notice of either the commission or contractor, promptly convene, and modify the original estimate as to the cost or time, or both, by adding to or taking therefrom the additional cost or time fairly attributable to the changes made in said plans and specifications.

5. The construction of breakwaters, either to protect the Atlantic or the Pacific end of the canal, shall not be included in the estimate of the said committee of the cost and time of the construction of the said canal. Should the commission subsequently decide upon the construction of breakwaters, or upon the construction of any additional reservoirs or dams or other work, not provided for in the plans and specifications at the time of their submission to the engineering committee, supplemental estimates shall be made by the committee, or a similar committee to be appointed in its place, of the cost and time required for the construction of such breakwaters, reservoirs, dams or other work upon the same basis as the estimates are made for the time and cost of the completion of the canal proper.

6. The estimates of the time and cost of the main canal construction work herein contemplated shall be completed if possible, but with due regard to the importance of the subject, within ninety days, and in any event within six months from the signing of this contract, and shall fix the cost and time as of the date when completed. From the estimated cost, the cost of any construction work upon the canal done by the commission after such date shall be deducted, and to the estimated cost the cost of any work done by the contractor before such date shall be added.

ARTICLE X.—DEFAULT BY THE CONTRACTOR.

1. Should the contractor at any time fail to observe any of the material obligations of his contract; or should he fail at any time to proceed with reasonable diligence in the construction of the canal, so that after excluding delays due to acts of God or public enemies, or an order or default of the commission, the canal, in the judgment of the chief engineer, cannot be completed within 20% more than the estimated time for its completion; or should the contractor fail to keep employed at work upon the canal a force of workingmen sufficient in the judgment of the chief engineer to complete the canal within 20% more than the estimated time, or should the contractor within three months after notice from the chief engineer fail to increase the working force to any extent prescribed by the chief engineer within the number that can be efficiently employed upon the said work, having due regard to its progressive condition; or should the work done by the contractor in the judgment of the chief engineer of the commission be done in an unworkmanlike manner, or in violation of the directions of the chief engineer; or should any materials put into the dams, locks, auxiliary works or other parts of the canal by the contractor be unsound or defective, and such as in the judgment of the chief engineer are calculated to impair the structural strength and efficiency of the canal; or should the contractor's current actual cost of construction at any time, in the judgment of the chief engineer, exceed by more than 20% that part of the total estimated cost of construction properly proportionable thereto; or should the contractor become insolvent or pass into the hands of a receiver; or should the contractor fail to satisfy any judgment that may be rendered against him within 30 days after the same shall go to execution, or become incapacitated for the proper discharge of his duty under this contract, by reason of legal or other complications, the commission through the chairman may by ten days' written notice served upon the contractor declare the contractor to be in default.

2. In any case in which the contractor is declared to be in default, as aforesaid, the commission may (1) either allow the contractor to resume work upon the canal, sub-

ject to such conditions, forfeitures and penalties as it may impose, or (2) take possession of and assume control and direction of the work of the construction of the canal, and may complete it either directly through its own agents or employees, or (3) may re-contract any unfinished work privately or by public advertisement upon the basis herein outlined, or on any other basis, to any contractor or contractors that it may select; and in any event may charge against the contractor and his sureties the additional cost of doing the work which the contractor agrees under his contract to do, and may collect the same from the contractor or his sureties, as damages, and should the construction of the canal be delayed beyond the estimated time by the default of the contractor, may collect, in addition, from the contractor or his sureties for each month in excess of the estimated time the penalty provided for under this contract.

3. And in any and all of the foregoing events, the commission shall have the right to withhold, pending the final adjustment, any balance otherwise due the contractor and proceed in the courts of the United States against the contractor or his sureties forthwith, or at any later period that it may deem advisable, to collect any damages that it may be entitled to either in law or in equity, whether damages specified herein or damages additional thereto allowed by law.

4. The contractor and his sureties covenant that in all cases where the commission so elect the damages sustained by reason of the default of the contractor may be assessed by the chief engineer subject to review by the chairman of the commission; and the final award of damages as determined by the chief engineer or chairman shall be paid to or recovered by the commission from the contractor or his sureties, under the terms of the contractor's bond, or the commission or the United States may sue to recover the actual damages sustained, treating the said award as prima facie evidence of the damages sustained and throwing upon the contractor and his sureties the burden of showing that the said award was the result of fraud or collusion upon the part of the chief engineer or chairman, or that it was arrived at contrary to the provisions of this contract.

ARTICLE XI.—TERMINATION OF CONTRACT WHEN CONTRACTOR IS NOT IN DEFAULT.

1. Irrespective of any default upon the part of the contractor, the commission reserves the right to terminate this contract at any time in its discretion upon the terms of paying to the contractor the entire cost of the construction work performed by him to such time, estimated in the manner hereinbefore provided, and the percentage earned by him upon such cost, provided that the total percentage payable to the contractor, including debits against him authorized under the contract, shall not in any event be less than $500,000, and provided further that, should the contractor have done at such time less than one-third of the work contracted to be done, he shall be paid 1% additional. The percentage actually accomplished in such case shall be fixed by the chief engineer.

ARTICLE XII.—DECISION OF THE CHIEF ENGINEER.

The decision of the chief engineer in the absence of fraud, misconduct or a palpable error apparent on the face of any decision or award, to the extent that it may not be modified by the chairman of the commission, shall be conclusive and binding upon the contractor: (1) Upon all questions submitted under the foregoing provisions of this contract to his determination. (2) Upon the question whether there has been a substantial breach of contract upon the part of the contractor. (3) Upon the question whether the contractor is in default. (4) Upon the character and extent of the damages sustained by commission or the United States from any breach of contract or default upon the part of the contractor.

ARTICLE XIII.—DEFINITIONS.

1. "Commission" means the present Isthmian Canal Commission or any successor thereof or any individual, officer or department of the United States to whom or to which the duty of constructing or arranging for the construction of the Isthmian Canal may hereafter be intrusted by law or executive order; and "chairman of the commission" means any successor exercising the chairman's present functions. All action reserved to the commission hereunder may be executed and carried out by its chairman. Any rights secured to the commission hereunder shall also be deemed rights secured to the United States of America, and, if that course be deemed advisable, may be enforced in the name of the United States.

2. "Chief engineer" means the chief engineer of the Isthmian Canal Commission, or any successor thereof, or his deputy or substitute that may be designated by the said commission or its successor. In all cases where action is provided to be taken by the chief engineer, similar action taken by the commission or its successor shall be equally effective.

3. "Engineering committee" means either the original engineering committee, or any similar committee that may be appointed in its place; it not being contemplated that the engineering committee will be maintained as a permanent organization.

(4) "Contractor" means contractors, or the employees of any contractor, or any subcontractor or employees when doing the work of the principal contractor, or the successors or assigns of the contractor.

5. "He," "his," or "him" means in the proper case "it" or "its," "they," "their," or "them."

6. "Surety" means "sureties," and whatever is required of any one surety shall be required of all.

## DEVICES TO KEEP RAILROAD SWITCHES FROM BECOMING CLOGGED WITH SNOW AND ICE.*

By Francis G. Shaw.†

The following claims for these devices are made:

1. The automatic melting of snow as it falls, blows, or is swept into a switch.

2. The disposal of snow in the form of water which is absorbed by the ground beneath the switch.

3. Doing away with all unskilled labor in or around switches during storm.

4. Impossibility of switch becoming inoperative through freezing or clogging.

5. Less chance of accidents, especially at night.

6. Financial economy and the saving of money to the railroad.

7. All parts light, readily removable, and easily handled.

There are two systems, one a gas-burning device, the other a hot oil circulation. The gas is preferable and has many points of superiority over the oil, the latter being designed for use where gas is not readily obtainable. The fundamental principle of both systems is identical. The heat is delivered between the ties, is there confined, economically distributed and only allowed to escape at the points needing protection.

Each tie space is converted into a closed box by means of light galvanized iron covers. These covers are designed to lie above or below the cross rods and bars. In either case they are readily removable. The only escape for the warm air in each box is up through the open slip. When the systems are in operation, the frost is driven out of the ground. Perfect natural absorption is thus obtained, and no water can lie in or around a switch. This was seen last winter in the yard of the Boston & Maine R. R. at Boston, where the oil system was tried.

### GAS HEATING.

Gas heating is cheap, entirely automatic, and exceedingly efficient. From underground mains which parallel each switch or group of switches, a pipe is led to each tie space. Connected to this pipe by means of a short length of heavy hose is a ½-in. burner pipe running the full width of the switch. This pipe has an air mixer on the inlet end and is pierced throughout its length with 1/16-in. holes on 2-in. centers. An automatic lighter, positive in action, is placed at each end of the pipe. The pipe burner gives a small, light blue, non-sooting flame about ¾-in. high. The intensity of this flame can be regulated by a valve.

Over the burner is a reflector, and above that the cover. The flame is thus well protected from drip or from being extinguished by the draft caused by passing trains. Should it be extinguished, however, the automatic lighter will at once relight it.

Tests made last spring with the thermometer at 65° F., and with a flame 1½ ins. high, showed a temperature of 365° F. in the tie space directly under the cover, and a gas consumption of 510 cu. ft. per hr. for a double-slip switch having 30 tie spaces. With gas at 90 cts., this represents a cost of 46 cts. per hr. This, however, is high, as the system would need to be run at such a heat only in the severest blizzards.

The system by its very nature shows economy. It takes a great deal of heat to melt snow that has already fallen, or ice already formed, but it takes comparatively little to melt snow as it is falling or to prevent water from freezing.

With the gas system, distance from the source of supply does not have to be taken into account. The ½-in. burners are readily disconnected from the supply pipe when tamping is to be done. The covers can be swung back or entirely removed when adjustments are to be made. The opening of the cock in the main supply pipe at the meter is all that has to be done to start the system. The intensity of the heat of each switch is separately regulated by a valve at the supply end of the branch main.

Should any one tie space show, by accumulation of snow upon it, that its burner is unlighted, a new lighter can be at once slipped into place. A man can carry a pocketful of these and replace worn or damaged ones in a few seconds. They cost about 15 cts. and will last a winter through if not damaged.

### OIL HEATING.

An oil heating system can be used to great advantage at junctions or in places where gas is not to be had. It can be installed in or near the signal tower, and can be used as a heater for it.

The oil is heated by exhaust or live steam to the temperature required. It is forced out through 2-in. pipes to the switches and is returned to be reheated.

A boiler, a tank, a heater, and a pump are all the machinery required. Starting the pump and turning steam into the heater are all that is necessary to put the system in operation. Once used, the steam is trapped back to the boiler to secure economy.

The supply and return pipes are buried and thoroughly insulated. The pipe heating the switch enters into the first tie space, returns again in that space and passes around the end of the next tie into the next space. The operation is repeated throughout the length of the switch. Where the pipes are exposed outside the covers they are insulated.

The oil used has a very high fire test and a low cold test. When the system is lying idle in cold, clear weather, the oil will not freeze and burst the pipes. It retains its heat much longer than does water, and can, therefore, be circulated through a much greater length of pipe.

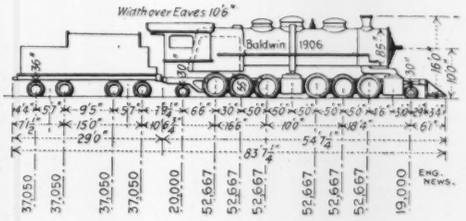
The covers in connection with this system are the same as those used with gas. The switch coil is coupled together with unions in order to allow the separate double lengths between the ties to be readily removed. The oil can be circulated at any temperature, at any speed, and in any quantity according to the weather conditions. The system is extremely flexible and most simple.

*A paper presented at the Washington meeting of the Railway Signal Association.

†Associated with the International Switch & Signal Co.

## WHEEL LOADINGS OF THE MALLET DUPLEX COMPOUND LOCOMOTIVES ON THE GREAT NORTHERN RY.

We published in our issue of Sept. 20 a photograph of the huge new Mallet duplex compound locomotive for the Great Northern Ry., the largest locomotive ever built. A correspondent has requested additional information as to the wheel spacings and wheel loadings. We therefore present, through the courtesy of Mr. R. D. Hawkins, Mechanical Engineer, a cut showing




The Largest Locomotive Ever Built. Wheel Spacings and Wheel Loadings.

these particulars. We may note here that the total weight of the engine and tender, when the latter is carrying its full load of coal and water, is 503,200 lbs. As the total wheel base of engine and tender is 73 ft. 2 ins., the average load per foot imposed by this locomotive on a bridge or other track structure is 6,870 lbs.

A REFUSE SCREENING PLAN for Bethnal Green, England, has been carried out on the advice of Mr. E. E. Finch, Assoc. M. Inst. C. E., Borough Engineer. The plant was designed and built by the Chain Belt Engineering Co., of Derby, England. It includes a coarse screen of fixed bars placed over a conical pit, an inclined bucket conveyor, an inclined rotary screen, a furnace, a Babcock & Wilcox boiler, and finally an engine that utilizes steam from a part of the refuse to operate the plant. The fixed screen is composed of tapered steel bars 3 ins. deep, averaging ½-in. in thickness and spaced 2 ins. c. to c. The bars are slightly inclined and are supported by steel girders. The refuse carts are tipped onto the screen, and in some four of five minutes' time each load of refuse is forked over and the paper, tin cans and other large refuse removed. The finer material falls into the pit and is removed therefrom by the bucket elevator. The buckets are 2½ ft. in length and are mounted on chains running over wheels spaced 40 ft. c. to c. The inclined screen has a length of 20 ft. and is perforated with holes of three sizes, being in general like the ordinary screens used with stone crushers. Paper and other combustible refuse sorted out during the forking process is burned in the furnace. The plant has a reported capacity of 100 long tons a day. The elevator and screen are driven by a 16-HP. horizontal engine. The ashes and other fine material from the screen are removed by barges, but their final disposal is not stated.

# ENGINEERING NEWS

**A Journal of Civil, Mechanical, Mining and Electrical Engineering**

Published every Thursday by

THE ENGINEERING NEWS PUBLISHING CO.

220 BROADWAY, NEW YORK

BRANCH OFFICES

CHICAGO: 1636 Monadnock Block
WASHINGTON, D. C.: Home Life Building
ATLANTA: Austell Building
RUDOLF MOSSE, BERLIN AND HAMBURG, GERMANY

SUBSCRIPTIONS

United States and Possessions, Canada, Mexico and Cuba, One Year, $5.00.

Foreign Countries, Regular (Thick Paper) Edition, One Year, $9.00. (£1-18-0.)

Foreign Countries, Thin Paper Edition (Construction News Supplement Omitted), $7.00. 29 Shillings, 35 Francs or 29 Marks. Remit directly to our office.

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Entered at the New York Post-Office as Second-Class Matter.


What is a railroad? The Century Dictionary defines it as "A road upon which are laid one or more lines of rails to guide and facilitate the movement of vehicles designed to transport passengers, freight, or both."

That is a good, broad description and will doubtless satisfy American engineers. On the other side of the water, however, the definitions built by irresponsible and unlicensed dictionary makers are not sufficient. The Supreme Court of Germany lately gave an official definition of the word "railroad," which is quoted in full by our German contemporary, "Stahl und Eisen," with an appreciative reference to its clearness and terseness.

As some of our readers may be interested to see what a railroad looks like to the official German mind, we have been at the pains to translate this definition into English, giving as nearly a literal rendering as is possible. The result follows:

> A railway is an enterprise projected for the repeated carriage of persons or things over not inconsiderable distances on metallic base which in point of consistence, construction and evenness is designed to make possible the transportation of large masses or a relatively high speed of transit, and which through this characteristic, combined with the associated motive power (steam, electricity, animal or human muscle power, or in a railway of inclined surface the mere weight of transportation elements and lading, etc.) is enabled, in the operation of the enterprise upon it, to produce a relatively tremendous effect, according to circumstances a useful effect as intended or one destructive to life and injurious to health.

We guarantee that no clearness has been sacrificed in making the translation, and that at the same time the above rendering maintains all the conciseness of the original. The English sentence contains 113 words, as against 115 in the German original.

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A very misleading but apparently well-intentioned article entitled "Does the Drinking of Water Give Typhoid Fever?" appeared in the "Medical Record" of Aug. 11, 1906. The author, Dr. R. G. Eccles, of Brooklyn, N. Y., starts out with the surprising paragraph:

> That the development of typhoid fever is connected with the use of infected water there is no reasonable room to doubt. The facts substantiate this hypothesis too firmly for it to be likely ever to be seriously shaken. That typhoid fever results from the *drinking* of infected water is quite a different proposition, and one that there are many reasons for doubting. The general belief among medical men, at present, is that the drinking of polluted water gives this disease. Since the polluted water does, somehow, give the disease, the assumption has been made that it results from the drinking of such water. There is no recognition of the fact that other explanations are possible and may be better. A diligent search of the literature of this disease has failed to reveal any evidence whatever that the drinking of water ever caused a single case, that the drinking of water could possibly start a case, or that there are any indications pointing to the possibility that spring, well, river, or hydrant water can reasonably be charged with having probably started any particular case. The belief, though almost universal among medical men, that typhoid fever is started by the drinking of water, appears never to have met with the slightest support from any facts. So far as can be discovered from the literature it is a pure assumption, unsubstantiated by either experiment or experience. It seems to have been taken for granted that, since the water and the disease are related to each other, the relation must be through the particular water which we drink; this, too, in defiance of known facts that stand in opposition to so gratuitous an assumption.

Any one writing on so vital a question as this, and a question, too, regarding which the general public is so likely to seize and act upon wrong impressions, should spare no pains to make his meaning so clear that he who runs may read. This Dr. Eccles fails to do, either in the paragraph which we have quoted or in the course of the remainder of his seven-column article. What this physician apparently wishes to prove is that water is what might be termed an intermediary vehicle in the spread of typhoid fever, but that milk and other foods contaminated by water, rather than water that is actually drunk, are the actual vehicles that convey typhoid germs in dangerous quantities to the human system. In addition, the author lays great stress upon the agency of flies which have been in contact with fecal matter, in conveying typhoid germs to food. This agency all well-informed persons are willing to give due weight, but in the article in question it appears to us undue weight is given to both the part played by flies and the part played by contaminated food in the spread of typhoid.

While making sweeping assertions at various places in the article to the effect that there is no literature or no proof of the spread of typhoid by drinking water *per se*, the author cites in support of his own theory many references and evidences which are no more conclusive than many that he might find in support of the drinking water theory. Neither the specific citations at the end of his article nor the article itself show that the author has ever seen, much less examined, the literature and statistics bearing upon the relation between drinking water and typhoid fever. We do not, however, lay any great stress upon the fact just named. No great harm could be done in submitting the thesis that drinking water in and of itself has never been *specifically proved* to have caused a case of typhoid and that food as a culture medium is absolutely essential to multiply the typhoid germs in water to sufficient proportions to give rise to the powerful internal disturbances due to the typhoid germ in the human system when once it gains a hold there. What we do find fault with is that the author should conclude his development of this thesis without pointing out that even if his theory be true it is scarcely less important that public water supplies be protected from sewage pollution, and if polluted that they should be thoroughly purified before they are made available for human consumption. We have said above that no great harm could be done in maintaining the food as against the drinking water theory of the spread of typhoid fever, but the interests of truth and the public health compel us to add, in conclusion, that if there were any likelihood that this theory would be accepted its promulgation would do great harm. Food should be guarded against typhoid infection from water and flies and in some cases from dust, as has scarcely more than been dreamed of heretofore, but at the same time there should be increased vigor in protecting drinking water, as such, from typhoid pollution.

The protection of drinking water, for 99% of the population of city and country alike, means the protection of all water used for household and industrial purposes, and it therefore seems a pity for any one, and particularly for a physician, to say anything that even tends to divert attention from that fact.

## THE CONTRACT FOR BUILDING THE PANAMA CANAL.

As announced in our last issue, bids are to be opened on Dec. 12 for the construction of the Panama Canal. The magnitude of this work, the unusual conditions under which it has to be done and the very novel plan that has been adopted for securing the advantages of contract work, while eliminating its well-known defects, makes the matter of extraordinary interest to the whole engineering world.

On another page of this issue we have presented, practically in full, the terms of the contract on which bids are invited; and since it is difficult for the ordinary reader to grasp the whole significance of this peculiar contract without long study, we have explained below just what the contractor is to do and what are his chances of profit and loss.

First, however, we may make clear the great difficulty which the Commission has been under in dealing with the problem of construction:

As most of our readers know, there has long been agitation to have the canal built by contract. Many people have been seriously worried lest this great piece of public work should be carried out with no opportunity for contractors to make a profit. Various parties have been ready and anxious to take a contract for the entire work for a lump sum, and have waxed indignant over the wasteful wickedness of the suggestion that the Government might execute the work by day labor under direction of its own engineers.

Through all this agitation and wire-pulling, the President and those whom he has selected to carry forward this great work have gone steadily forward, doing the work that was necessary to be done, paying no heed to the agitation of those who agitated for their own pockets all the time; but industriously laying the necessary foundation for the rapid and efficient construction of the interoceanic canal.

The difficult question of whether a sea-level or a lock canal should be adopted was settled, as our readers know, some months ago; but a question quite as difficult, in some respects even more knotty, is whether the canal shall be built by the Government itself or by contractors. There are strong arguments on both sides of this question; and as a final solution the Canal Commission has chosen a middle course. Under the plan adopted the Government will carry on such parts of the work as cannot well be delegated to a contractor, such as the Zone Government, policing, sanitation, hospital service, and the operation of the Panama R. R. and steamship lines; but it will turn over to a contractor the actual building of the canal.

Engineering News, as its readers know, has steadily opposed the letting of the canal work to contractors in the ordinary way. We have maintained that the division of the work into sections would give rise to the greatest difficulties between the separate contractors over their relative rights on the Panama R. R., their respective labor supply, and many similar matters. On the other hand, if it were proposed to let the whole work outright for a lump sum, there are no contractors big enough to give good bonds to complete a job likely to continue for ten years and to involve a hundred million dollars. Even if such a contractor could be found, real competition for such a contract would be out of the question.

While we have thus opposed letting the work as an ordinary contract, we are perfectly well aware of the difficulties in carrying out so vast and complicated a piece of work as the Panama Canal wholly by day's work. As Mr. Shonts set forth in the letter published in our last issue, the Panama Canal Commission labors under great difficulty in building up a working organization for carrying on construction operations that can compare in the ability to hustle and to get results with the organization of the best contracting firms. How to secure the services of such organized hustlers to push the work was the problem; and the solution has been found in a novel form of contract, the exact like of

which has never before been tried, but which is worth the very careful study of every engineer and contractor.

In the first place this contract carries into effect a principle for which Engineering News has long contended. It places the burden of risk on the Government, where it belongs, and not on the contractor. As our readers know, a very large amount of contract work is now done, not on the lump sum basis, but on the basis of cost-plus-a-fixed-sum or cost-plus-a-percentage. The great defect of these forms of contract, however, is that they give the contractor no particular incentive to keep the cost down or to push the work hard. On an ordinary job, of course, the contractor may do well in both these particulars for the sake of his business reputation; but on a ten-year job in a tropical climate, some stronger incentive to good work is necessary.

What the Panama Commission had to do was to find a way whereby the Government could bear the entire cost of the work and yet give the contractor a big inducement to hustle, year in and year out, and to economize at every point. The contract on which bids are invited actually does this. It offers to the wide-awake, energetic contractors of the United States a way to win fortune and reputation by carrying out the greatest engineering work in the world, with a minimum of risk, and with opportunities for large profits.

To comprehend now what the contract involves, understand in the first place that the Government is to pay the contractor the entire cost of the work, be it more or less. No matter what changes are made, no matter how prices go up, or what vicissitudes attend, the contractor is at absolutely no risk, so far as his expenditure on the work is concerned. For all that he pays out on construction during each calendar month the Government agrees to reimburse him in full by the fifteenth of the following month. Thus he has practically no capital tied up in the work to meet his pay-rolls. He does not even have to invest capital in working plant—for the dredges, steam shovels, cars, locomotives, etc., are all to be furnished by the Government; which also furnishes all materials—lumber, cement, iron, steel, etc. Thus the contractor has to invest practically no capital, and his risk in executing the work is reduced to the lowest possible figure.

For the execution of the contract the contractor is to receive as aforesaid the actual amount which he expends on it, month by month, plus a percentage (later) on the estimated cost of construction. On Dec. 12 contractors are to submit bids stating what percentage on the estimated cost they will accept. Now comes the feature whereby contractors are given the incentive to do their best work. Estimates are to be made of the cost to the contractor of completing the work and of the time required for such completion. If the contractor does the work for *less* than this estimate and in *less* time he receives a premium. If the work costs more and takes longer than the estimate, he pays a penalty. Stated in figures: For every $5,000,000 which the actual cost of the work exceeds the estimated cost, there will be deducted 0.5% from the percentage bid by the contractor; but if the contractor succeeds in doing the work for *less* than the estimated cost he will be entitled to one-third the actual saving made. The bonus or penalty for time is $100,000 for each month over or under the estimated time.

The estimate of cost and of time for completion is to be made up by an engineering committee of five members, of which two are to be appointed by the contractor and three by the Commission. It will be noticed that this estimate of cost does not at all affect the guarantee to the contractor that he shall be paid the full amount that he expends in construction. In this matter he is at absolutely no risk. All that he risks is his profit on the work.

To give a clearer idea of just what opportunities this contract offers, let us take actual figures as follows: The Members of the Board of Consulting Engineers who recommended the lock canal last spring gave a detailed estimate of its cost, which amounted to $116,421,000. To this they added 20% for administration, engineering and contingencies; but this addition need not be made here, for the administration and engineering are assumed by the Government, and the "contingencies" item, while proper enough in an estimate made for the purpose of comparing two rival types of canal, is not to be included in estimating the actual cost to the contractor. From this sum of $116,421,000, however, we must deduct an amount of $5,300,000 for breakwaters in Limon Bay, which are not to be included, leaving a remainder of $111,121,000.

This estimate of the Board of Consulting Engineers, however, was made up on the basis of ordinary contract work, where the contractor furnishes everything and is entitled therefore to a fair profit for his risk and for interest on his investment. In the contract before us, however, the Government furnishes the entire working plant, and all the materials. This means, we should say, that at least $20,000,000 should be deducted from the above amount, leaving $91,121,000. If now we deduct 10% from this as an average allowance for contractor's profit, we have $82,008,000 as the approximate cost to the contractor of completing the Panama Canal under the conditions of the contract before us.

It must be understood, of course, that this is only a rough method of approximating the probable cost to the contractor, and that from the data and experience now accumulated on the Isthmus much more accurate estimates will now be possible than those made a year ago by the Board of Constructing Engineers. It would not be surprising if the final estimate showed a very considerable reduction from the above figures.

For our present purpose, however, suppose that we assume the official estimate of cost to the contractor to be set at $80,000,000, in round numbers, and suppose the accepted bid of the contractor to be 5% on the cost of construction. Suppose also the official estimate of the time required for construction to be eight years. If the actual cost of the work is equal to the estimated cost, and it is completed in exactly eight years, the contractor will earn a profit of $4,000,000, or $500,000 per year. Out of this profit he will have to pay the cost of his own organization, administration, legal and general expenses, interest, taxes, cable service, "and all expenses to which he may have been put by reason of his own negligence or inefficiency or by reason of any unsound or imperfect materials put into the work, or any imperfect preparation or use of material." The contractor also has to stand damage suits for accidents and injuries on the works. It is to be specially noted, however, that the contractor's expenses for foremen and superintendence and clerical service on the Isthmus are to be figured into the cost of the canal, which the Government is to pay for anyway. Apparently, therefore, the contractor should be able to keep down the expense bill which he has to bear himself to a very moderate figure.

Now let us see how the contractor will fare in case the actual cost varies from the estimated cost. Suppose first that the actual cost to the contractor is $90,000,000 instead of $80,000,000. Then the contractor will receive only 4% on the estimated cost of $80,000,000, or $3,200,000. On the other hand, suppose the contractor is able to carry out the work at a saving of $10,000,000 from the estimate; then he will be entitled to one-third of this in addition to his $4,000,000, and his total gross profit will be $7,333,333, or nearly a million dollars a year. It will be apparent from this that the penalties for an excess of cost over estimate are small compared with the premium for keeping the cost below the estimate. The intent evidently was not to unduly increase the contractor's risk of losing all his profits while still giving him a great incentive to keep down the cost.

Turning next to the premiums and penalties for time: Actually, when the interest on its investment is considered, the Government is losing much more than $100,000 per month by every month of delay in completing the canal. The penalty was made thus moderate, however, no doubt, in order not to unduly increase the contractor's risk. Suppose the time of completion is one year later than the estimated time. Then the contractor would lose $1,200,000 from his profits, leaving him a gross profit of $2,800,000, assuming as before a 5% bid and an actual cost equal to the estimated $80,000,000. Even if we assume a two years' delay and a $10,000,000 increase of cost over the estimate, he would still have left $400,000 profit, or enough to pay probably the running expenses of his organization during the ten years of construction.

There seems, then, the veriest minimum of risk involved to the contractor in this work, while the chances of profit to a contractor with the proper organization to push the work rapidly and economically, are certainly very bright. The contractor has no responsibility for purchase of materials and machinery, or for policing, hospital service or sanitation. His whole energies can be devoted to pushing the work itself, and he has good chances of earning a very large bonus by saving in the cost of construction and in the time. So good are these chances and so great is the bonus offered for a saving in cost and time that it would not be surprising to find contractors bidding considerably smaller percentages than the 5% which we assumed above.

Of course it must be stated that the number of eligible bidders is not very large. The invitation to bidders specifies that any contractor or association of contractors bidding must have an available capital, over all debts and incumbrances, of $5,000,000. In the award of contracts, moreover, the qualification of the bidder as judged by his past record on other works and the working organization which he has available will be taken into account. It will, therefore, be of no use for concerns to bid unless they have a large experience and good records in the execution of engineering contracts.

The provision for bidding by associations of contractors is intended to afford an opportunity for contractors of comparatively moderate capital to join together in submitting bids. The call for proposals specifically states that such an association of contractors, combining the experience and organizations of several large contracting firms with established reputation, will be given preference in the award over any single firm. Any such association of contractors will have to be organized in legal form with a definite assignment of financial responsibility to its several members, and doubtless also with a definite arrangement for so apportioning various parts of the work that such work as hydraulic dredging, dam construction, lock construction and excavation may fall to the members best equipped to perform it.

As the contract is not necessarily to be awarded to the lowest bidder, the opportunity is one never before equalled for contractors who can show the highest records for economical and rapid performance on their past work and who possess thoroughly efficient organizations. The opening of bids on Dec. 12 will be awaited with the greatest interest.

## LETTERS TO THE EDITOR.

### Another Labor-Saving Short Cut in Earthwork Computations.

Sir: I have hit upon another way of converting cubic feet into cubic yards, which is new to me, and I thought it might be to some of your readers.

Instead of dividing by 27 multiply by 37 and point off three places. This gives an amount that is just one yard too small in 1,000 yds. Now if the decimal point is moved to the left three places farther and the last amount is added to the first it gives a result that is just 1/1,000-yd. too small in 1,000 yds., or one in a million.

Yours truly, J. J. Rinn.

1526 Snyder Ave., Philadelphia, Pa., Oct. 9, 1906.

### The Proper Uses of Puzzolan Cement.

Sir: Although the Engineering News has given a reasonable amount of space to valuable matter on concrete, during several years last past, I have patiently waited in vain for matter relating to the adaptability of the Puzzolan cements. This subject is of vital local interest to

some of us, and I and others would appreciate a discussion on this line, both editorially and by users. Is it suitable for use in exposed positions where subject to frost? As in retaining walls, building foundations above ground, bridge piers, culverts, catch basins, etc. In concrete sewers on a steep grade, will it stand the attrition of flood water carrying silt, sand and rock?

I believe the subject worthy of discussion.

Youthful.

[Puzzolan cement is described, its "proper uses" stated and specifications for it, including testing, are given in Professional Paper No. 28, Corps of Engineers, U. S. A. (Washington, D. C.; 1901). The "Paper" as a whole is a comprehensive report by a board of engineers on the properties and tests of hydraulic cement, and was printed practically in full in Engineering News of Sept. 12, 1901. Under "Proper Uscs" the board said:

Puzzolan cement never becomes extremely hard like Portland, but Puzzolan mortars and concrete are tougher or less brittle than Portland. The cement is well adapted for use in sea water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers and drains, and underground works generally, and in the interior of heavy masses of masonry or concrete. It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

Since the date of the report Puzzolan cement has come into more extensive use than before. Doubtless many of our readers could give experience with the material which would be of value to our correspondent and to others as well.—Ed.]

### What Allowance Should be Made for the Investment in Contractor's Plant in Estimating the Cost of Contract Work.

Sir: I have read with much interest, in your issue of Oct. 11, Mr. Emile Low's contribution describing the cost of deep water dredging with a clam-shell dredge in Buffalo Harbor. In the table on p. 375, Mr. Low estimates that the average cost to the contractor of this dredging was 9.3 cts. per cu. yd., whereas the contract price was 18 cts. per cu. yd. The hasty reader would doubtless conclude from this that the contractor on this work doubled his money. If we analyze Mr. Low's figures, however, we find that he reached his figures for cost by assuming an annual depreciation of 10% on a dredging plant costing $92,000. Any contractor who undertakes to carry out difficult and important works with only 10% allowance for annual depreciation on the plant used, will probably not continue in business very long. Of course for ordinary classes of work, where the dredges or shovels or dump-car equipment used is practically the same that is used on other work elsewhere, a moderate allowance for annual depreciation may be made; although even here it is hard to find anything which a contractor uses that will not be worn out and in the scrap heap before ten years have passed. But when it comes to doing work involving such unusual features as the deep-water dredging at Buffalo, where a special dredge is designed for the work, a contractor must figure on getting back his investment in the course of three to five years, at most, and on small jobs a machine must pay for itself even sooner. It very often happens at the end of the execution of an important contract that a plant which has cost a great deal of money and is still in excellent condition has to be sold for a very low figure because it is not suited to ordinary work. I think this matter worth bringing to the attention of the profession, since there is, I believe, some tendency among engineers to overlook matters of this sort in estimating the cost of work to the contractor.

Yours very truly,

New York, Oct. 13, 1906. "Finn MacCool."

### The Resistance to Distortion of Different Types of Reinforced Concrete Construction.

Sir: I read with some little interest your editorial of Sept. 27 regarding the book recently published by Mr. A. L. A. Himmelwright, M. Am. Soc. C. E., in which reinforced concrete was compared with other materials in its resistance to earthquake and fire in San Francisco. It seems to be a fact that there was a small amount of reinforced concrete in San Francisco and that the buildings in which concrete was used were, in general, of a composite character, with more or less structural steel rather than true reinforced concrete.

As regards the resistance of reinforced concrete to forces tending to distort and wreck the construction: Assuming the distorting forces to be of sufficient intensity to produce a certain distortion, regardless of the resistance offered by the construction, that form of beam or floor which can deflect the greatest amount, without destruction, would seem to be the type best fitted to resist earthquake shock.

Now, for the same working stress, the deflection of a floor or a girder varies approximately with the cube of the depth, hence, if we use flat slabs, without ribs, of somewhat greater thickness than are commonly used with ribs, we shall get a construction which is able to withstand greater distortion, without injury, than that which is commonly put up. For instance, with a slab 8 ins. thick, spanning 20 ft., an actual variation in the relative heights of different columns of $\frac{5}{16}$ to $\frac{1}{2}$-in. could probably occur during a shock without cracking the construction, because where reinforced concrete floors of beam construction have been used with beams of this span and 23 ins. deep from the top of the slab, a distortion greater than this has been observed, caused by faulty piers, and a deflection 50% greater than this noticed, yet the work was made good, without destruction of the beams, or appreciable injury to the construction.

As to the fireproof properties of concrete, it seems to the writer that, if we wish to put up concrete which will present a high resistance to heat, we must make a rich concrete, and its fireproof properties will be largely determined by the amount of cement used. That it is practical to put up a construction of flat slabs with column spacing from 16 to 20 ft. for heavy loads has been demonstrated by the writer's experience, as recorded in your issue of Oct. 4.

Yours truly,

C. A. P. Turner.

Phoenix Building, Minneapolis, Minn., Oct. 3, 1906.

### The Design of Hydraulic Dredges—Records of Practical Work by Engineers.

Sir: You are to be congratulated on publishing the interesting and valuable report of Mr. Henry N. Babcock, M. Am. Soc. C. E., on the performance of the hydraulic dredges "Manhattan" and "Atlantic," and also your able editorial referring to same. This report is very interesting in that it shows that a hydraulic dredge must be designed for the work it is intended to do. Such a machine is composed of many parts, and an error in the design of one of the apparently unimportant parts will sometimes greatly affect the output. This has been found to be true with dredges on the Mississippi River. The first three dredges built for the Mississippi River Commission were from contractors' plans, and considerable money was afterwards spent by the commission for alterations, so as to make them adaptable to the conditions that there obtained. To-day some of these machines could not be identified by the designer should the name be removed. The more recent dredges were from the plans made by the commission itself, and were, of course, adapted to this work and devoid of former mistakes.

The report is valuable in that it gives details of the betterments and costs, and especially in that it was the cause of your editorial: "That Engineers Are Practical." It is about time the fact be published that successful engineers *are* practical, or they would not be successful, and that the "old fogy" opinion that the engineer is a mathematical theorist be proven incorrect.

There is also a prevailing opinion that work performed by the Government through its civilian engineering staff is very expensive, and the above report explodes this. If any one would take the trouble to look up statistics it would be found that when a contractor fails, especially on Government work, it usually falls to the lot of the engineer to perform this work within his estimate, and he usually succeeds. You will find this especially true when new and difficult improvements on river and harbor work are undertaken. A number of such cases which have come under my observation during the eighteen years while I was connected with river and harbor work, could be cited to prove the above statement.

The reasons why cheaper and better work has been done by the Government are: First, that there is better organization; second, the prompt payment of salaries, wages and accounts; and third, the fact that the engineers are not usually satisfied with the cost of a piece of work, and are always studying and experimenting with new methods to reduce cost; while if a contractor is making approximately the percentage his estimate is based upon, he is satisfied and will not attempt improvements, because "experiments cost money."

Very truly, Wm. Gerig.

La Boca, Canal Zone, Oct. 3, 1906.

### Notes and Queries.

By an error of omission affecting two articles printed in our issue of last week, Oct. 11, we failed to give credit to the sources from which the two articles were compiled. The article on p. 372, "The Transporter Bridge at Newport, England," was prepared with use of information and illustrations from "The Engineer" [London]. The article on "A New Conduit for the Water Supply of Vienna, Austria," p. 376, was based on a longer descriptive article in the "Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins." In both cases our articles represent a considerable condensation over the original, and those specially interested may find somewhat fuller information in the original articles.

## THE SUPPRESSION OF INDUSTRIAL SMOKE WITH PARTICULAR REFERENCE TO STEAM BOILERS.*

By A. Bement,† M. Am. Soc. M. E.

It is a recognized fact that bituminous coal can be burned without smoke; also that the consumption of the volatile gases results in increased economy. In the author's opinion, the people who are to blame for present conditions, may be divided into three classes in the order of their responsibility:

First—Manufacturers of furnace apparatus.

Second—Consulting engineers and architects.

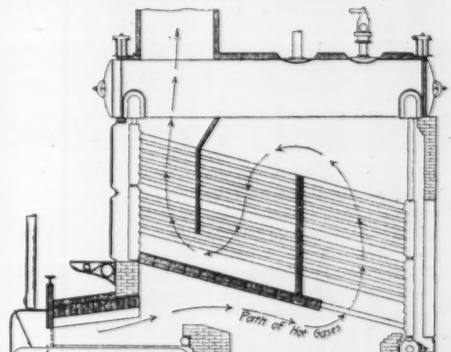
Third—Purchasers who operate the apparatus.

In considering the matter from the standpoint of manufacture, the important fact should be emphasized, that with one possible exception there are, strictly speaking, no smokeless apparatus made. This single exception will be mentioned later, but it is first desirable to outline the requirements governing smokeless combustion. They are:

First—Uniform evolution of the volatile gas, which requires with a stoker a positively uniform feed of the coal.

Second—The location of a chamber of sufficient length or capacity between the fire grate and exit to the boiler, to ensure that the volatile gases shall become thoroughly mixed with the air which enters with them.

Such chamber, which the author has called a furnace, to distinguish it from the grate, must, of course, be made of refractory material to enable it to witstand the heat, and its walls necessarily become red hot. This has caused many people to believe that the high temperature in itself was the cause of the volatile gases being burned, failing to take into consideration the fact that the most important requirement is a thorough mixing of the gases with the air in the chamber. Failure to realize this fact has resulted in disappointment with many brick




A Steam Boiler and Furnace which will Burn Bituminous Coal Without Smoke.

arches, "Dutch ovens," etc. The chain grate, owing to its feed of coal being on a horizontal line, ensures a positively uniform rate in the feed, and consequently there is a steady evolution of the volatile gas, which will be burned if there is such furnace located between it and the boiler, and this apparatus may properly be called smoke-proof, because it is impossible for the operator to either cause, or allow the coal to be fed in other than a steady and uniform manner.

Even when a very large furnace chamber is used with any form of stoker (other than a chain grate) or a hand fired grate, a smokeless condition is dependent upon careful manipulation. For example, with a hand fire, if too much coal is added at one time, the evolution of gas will be greater than the mixing capacity of the chamber; or, with sloping grate stokers, when a large quantity of coal is poked or slides down the grate, the result is the same as when a large charge of coal is added to a hand fire. Thus the fuel feeding apparatus or method of manipulation, must not overtax the mixing capacity of the furnace chamber, if a smokeless result is to be secured.

The accompanying illustration shows the latest and best type of smoke-proof steam generator, its furnace chamber being formed by tiles covering the lower row of the tubes of the boiler. It is not a patented apparatus and may be adopted by any one who wishes to do so. In fact, many boiler plants now installed, may at small expense be altered so as to conform to all of its essential requirements.

While this particular improved apparatus has already been built when demanded by purchasers, no manufacturer is willing to erect it unless required to do so. The nearest approach to a smoke-proof apparatus in the form of a complete steam generator, offered by any maker, consists of a brick arch as an essential adjunct for the

*From a paper read before the Western Society of Engineers, Oct. 17, 1906.

†Consulting Engineer, 215 Dearborn St., Chicago, Ill.

direction of the gases against the tubes of the boiler, and when this manufacturer installs a chain grate under this arch, it becomes the above-mentioned exception to the rule. This does not mean, however, that a purchaser may not buy a boiler from one maker, a stoker from another, and with a little engineering produce an apparatus which is strictly smokeless, but that an entire apparatus of satisfactory character as a unit, cannot be purchased from any single manufacturer.

For a clearer understanding, it is essential that furnace apparatus be considered in two classes, one which is smoke-proof, the other depending upon careful manipulation for good results. This latter class may also be separated into two divisions, those which by reasonably careful working will be smokeless, and others, which it is very difficult to operate without smoke. Thus there are three grades of apparatus, the perfect, the moderately good and the bad.

The effort of health departments and smoke inspection bureaus should be to enforce the adoption of the perfect apparatus, proper manipulation of the moderately good and the abandonment of the bad.

## A METHOD FOR TESTING AND COMPARING SEWAGE SPRINKLERS.*

By Earle B. Phelps.†

In the application of sewage to the surface of filters of the trickling or sprinkling type, evenness of distribution is an essential factor. This is more especially true in the case of filters whose material is of so coarse a nature that there is little or no lateral movement of the sewage within the bed. If, on such a filter, one-third of the surface is receiving two-thirds of the applied sewage, it is quite evident that the rate of filtration on that area is twice the mean rate. This rate would largely determine the character of the effluent, and an effluent of the same character could be obtained at twice the rate of filtration if the sewage could be distributed in a perfectly even manner over the whole area.

To accomplish this distribution over the surface of coarse-grained filters, many types of distributor have been devised. Among the more important of these may be mentioned: (1) Systems of fixed troughs, designed either to overflow or to discharge through notches or orifices; (2) delivery arms rotating over circular beds, operated either by the flow of the sewage or by power, distributing through nozzles or by overflowing; (3) large overflow troughs moved laterally back and forth over the bed; and (4) fixed sprinkler heads (pressure sprinklers) discharging upward under pressure, or discharging downward (gravity sprinklers) upon sprinkling or spattering disks. The distribution effected by these various methods is necessarily more or less uneven, and the efficiency of a given system may be defined as the evenness of the resulting distribution, a perfect distribution being one in which each small unit of area is receiving its proportionate share of the sewage. Such a condition is approached, in theory at least, by well-designed distributors of the second and third types enumerated. Their efficiencies depend upon proper leveling, unobstructed openings and other details of design and operation which need not be gone into. Distributors of the first type mentioned cannot give perfect distribution. They distribute in lines, and as these lines are brought nearer and nearer together the distribution becomes more nearly perfect. In the Stoddart distributor the limit is reached and almost perfect distribution achieved by completely covering the filter with corrugated sheets of metal, the individual troughs being in actual contact. It is with the last group mentioned, pressure and gravity sprinklers, that the present discussion has to deal. Such sprinklers are fixed at definite points at or above the surface of the bed, and are designed to throw the sewage in a spray or spatter over the intermediate areas. The efficiency of their distribution, under given conditions of head, is determined entirely by their design, and the study of this efficiency is one which lends itself readily to careful experimental methods. The distribution is obviously not a perfect one, if for no other reason than that it is circular, and there must either be overlapping of the circles or intermediate non-wetted spaces, or both. Within each circle, moreover, there is generally a tendency to the formation of concentric rings of greater or less flow than the average, so that, if small units of area are studied, there will be found a variation in rate of flow along a radius. The definition of perfect distribution is one which is easily grasped, but the conception of a quantitative measure of the unevenness of the distribution is not so simple, and no attempt has heretofore been made to work out such a measure. Obviously the distribution is not measured by the wetted surface, although that expression is the best one which has thus far been used to describe the efficiency of a sprinkler. In the course of an investigation of pressure and gravity sprinklers now being made at this station, the need of some quantitative measure of the results was at once manifest. A mathematical analysis of the conditions involved was made, resulting in the definition of a "coefficient of distribution," which shows the mathematical relation between any observed condition of distribution and that condition which has been defined as perfect. In view of the ever-increasing importance which sprinkling filters are assuming in this country, it is thought wise to publish this preliminary description of the methods of testing employed and of the mathematical analysis of the results. A graphical representation of the conditions of distribution is first worked out, and from it the definition of the "distribution coefficient" is derived.

For the purposes of this problem let us assume that a pressure sprinkler is shooting up a spray of sewage, fountain-wise, the sewage falling over a circular area. Along any radius let us place a line of small, square collecting tanks of known areas, which we may designate the unit area. Let it be assumed, further, that the distribution along this radius is the mean of that along all radii. The variations along the various radii will be small, and the assumption may be completely realized, as is being done in our experiments, by revolving the line of collecting tanks about the center during the experiment. After running a suitable length of time the sewage is shut off and the amount collected in each small tank is measured. In the accompanying table a set of actual results is reproduced for the sake of illustration.

TABLE SHOWING RESULTS OF OBSERVATIONS OF DISTRIBUTION EFFECTED BY SEWAGE SPRINKLER.

| Tank No. | Radial distance (D). | Sewage quantity (Q). | D x Q. | Excessive quantities (Ex. Q). | D x Ex. Q. |
|---|---|---|---|---|---|
| 1 | 0.5 | 0.8 | 0.4 | .... | .... |
| 2 | 1.5 | 1.6 | 2.4 | 0.14 | 0.21 |
| 3 | 2.5 | 2.7 | 6.8 | 1.24 | 3.10 |
| 4 | 3.5 | 2.5 | 8.8 | 1.04 | 3.65 |
| 5 | 4.5 | 2.3 | 10.3 | 0.84 | 3.78 |
| 6 | 5.5 | 1.9 | 10.4 | 0.44 | 2.43 |
| 7 | 6.5 | 1.5 | 10.0 | 0.04 | 0.26 |
| 8 | 7.5 | 1.3 | 9.8 | .... | .... |
| 9 | 8.5 | 1.0 | 8.5 | .... | .... |
| 10 | 9.5 | 0.6 | 5.7 | .... | .... |
| Totals.... | 50.0 | | 73.1 | | 13.43 |

$$73.1 \div 50.0 = 1.46 = M.$$

In the first column are given the numbers of the collecting tanks, No. 1 being at the center. In column 2, headed "D," are given the distances from the center of the sprinkler to the centers of the corresponding tanks, the side of the tank being taken as unit distance. In the third column, "Q," are given the amounts of sewage measured in each tank at the end of the test. Any unit of volume may be employed. In this case the depths in the measuring tanks are used, these being proportional to the volumes. Now if these quantities, Q, are plotted as abscissae against the corresponding D values, as ordinates, we obtain a curve showing the relative distribution of the sewage along the radius. This curve is shown at "A" in the diagram. It shows the rate of discharge per unit area at any point whose distance from the center is known, and will be known as the curve of radial distribution. Since the radial distribution measured was assumed to be the mean of all radial distributions, the abscissa of this curve at any given distance from the center shows the rate of discharge at all points on a circumference described about the center at the given distance from it. Hence to obtain a curve showing the distribution on the whole circle, i. e., on an infinite series of successive circumferences, it is necessary to multiply the abscissa for each point on the radius by the length of the corresponding circumference, or what amounts to the same thing, relatively, by the radial distance of the point in question. In column four, "D x Q" in the table, are given the figures resulting from this operation. These quantities represent the relative rates of discharge of the sewage upon successive concentric rings of the circle, the width of the rings being unity and their distances from the center being the corresponding D. If now a new curve be plotted with these products just obtained as abscissae and the corresponding D values as ordinates, the resulting curve is the curve of distribution over the wetted area (curve B in the figure).

From its construction this curve has the following properties: the abscissa at any point shows the relative rate of discharge of the sewage upon a circumference at the corresponding distance from the center; the area of any vertical strip shows the relative total discharge upon the corresponding ring of the wetted circle; and the total area under the curve represents the total discharge from the sprinkler.

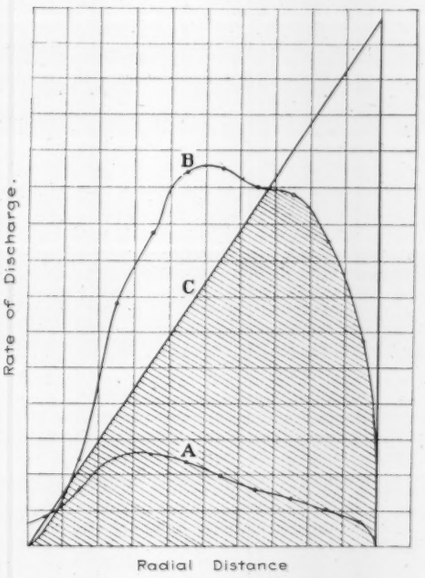



Diagram for Use in Comparing the Efficiencies of Sewage Sprinklers for Filter Beds.

It will next be necessary to construct the curve of perfect distribution. This curve must conform to the fact that the discharge upon all unit areas is the same, and hence that discharges upon all circumferences are directly proportional to their lengths, i. e., to their radii. Obviously, then, the curve is a straight line passing through the origin. Its slope is determined graphically by the fact that the area under the curve represents the total discharge from the sprinkler, and hence equals the area under the distribution curve already drawn. The latter area may be determined by means of a planimeter, and from the known base of the triangle its altitude may be computed. It may be calculated more readily but less accurately by adding up the column "Q x D" and dividing by the radius of the wetted circle (10). This curve is shown in the figure as curve "C."

We now have the curve of actual distribution and the curve of perfect distribution. There remains to be derived a mathematical expression of the relation between these two curves. The curves have a common area which is shaded in the diagram. From what has preceded it will be apparent that the more perfect the distribution the more nearly will the two curves coincide, and the greater will be this common area. Hence a direct comparison of the common area with the total area of either curve gives a numerical expression of the efficiency of the distribution. If the distribution be perfect the two

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curves will coincide, and the ratio, common area to total area, will be unity. If the distribution is very poor the common area will be small in proportion to the total, and the ratio will be correspondingly low. Moreover, while it is not so evident from the present brief description of the method, a more careful analysis of the mutual relations of these two curves shows that two distribution curves differing from one another in shape but yielding the same ratio of common area to total area represent conditions actually different but identical as regards relative distribution.

If we define the term "excessive discharge" as that part of the discharge from a sprinkler which is flowing upon any area of the filter in excess of the mean rate for the total area (represented graphically by that portion of the area above the straight line) then we may define the coefficient of distribution as the ratio of the total discharge minus the excessive discharge to the total discharge; or in algebraic form,

$$\text{Dist. Coef.} = \frac{T - E}{T}$$

or more simply,

$$\text{Dist. Coef.} = 1 - \frac{E}{T}.$$

Comparisons of the areas may be made quite readily by means of the planimeter. To obviate the necessity of multiplying to get the quantities, Q x D, a special form of plotting paper has been used, which performs the multiplications graphically. This paper has one set of coordinate lines vertical, as usual, and the other set radiating from the origin. Direct plotting of the figures used in curve A upon such paper will in reality give curve B, any given value having an actual magnitude upon the plot which is proportional to the horizontal distance from the origin.

While the plot as thus worked out is essential to a clear understanding of the conditions and of the definition of the coefficient, it has been found much simpler and sufficiently accurate in practice to calculate the coefficient from the observed data (see table). Adding up the column "Q x D" gives the area under curve B, representing the total discharge (T). Adding the column D gives a number representing the total wetted area; that is, it bears the same relation to the total area as the sum of the "Q x D" column does to the total discharge. Dividing the former by the latter gives the mean discharge (M) per unit area for the whole filter. If this mean discharge be subtracted from each value of Q which is greater than the mean, a set of figures are obtained which are shown in the table under the heading "Ex. Q." These figures are the excessive discharges per unit areas at the respective distances from the center. Multiplied again by the distances in the D column they give the excessive discharges for the concentric rings and the sum of the latter figures, column "D x Ex. Q", gives the total excessive discharge as already defined (E). We have now the two factors T and E for use in the formula

$$\text{Dist. Coef.} = 1 - \frac{E}{T}.$$

In the illustration used,

$$E = 13.4,\ T = 73.1,\ c = 1 - 0.18 = 0.82.$$

The coefficient thus derived refers to the efficiency of the sprinkler under the given conditions, and figured upon the area of the wetted circle. There remains to be derived the true coefficient based upon the total area of the filter portions of which between the circles may not be wetted. Each sprinkler must then be referred to the area of a square whose side is the distance between centers of adjacent sprinklers. Denoting the area of the square by "Sq" and of the wetted circle by "Cir," the final coefficient, C, may be found from the former coefficient, c, by the formula,

$$C = c \times \text{Cir/Sq.}$$

By the use of such a distribution coefficient it is possible to make experimental comparisons of both pressure and gravity sprinklers of various designs, and to test the effects of variations in head, rate of discharge, and other variables upon the distribution.

## DIFFERENT PLANS OF LETTING CONTRACTS.*

By Frank B. Gilbreth,† M. Am. Soc. M. E.

In accordance with the request of your Secretary, I have written this paper describing what is known as the "Cost-Plus-a-Fixed Sum" method of contracting. I shall first describe two other and probably better known forms of contract, namely, the "Lump Sum" contract and the "Percentage" contract, and then I shall explain in detail the "Cost-Plus-a-Fixed-Sum" contract, and then the "Cost - Plus - a - Fixed-Sum-Contract-With-a-Guaranteed-Maximum," which, as a matter of fact, is nothing more or less than a "Lump Sum" contract under another name.

I shall then state the reasons for selecting for our own business the "Cost-Plus-a-Fixed-Sum" contract exclusively and our reasons for believing that it is the only form of contract that is just equitable for both the owner and the contractor, and that it is the only form of contract whereby the interests of the owner and the contractor are made identical. I shall endeavor to prove that the best results cannot be obtained under the "Cost-Plus-a-Fixed-Sum" contract if the contractor takes contracts upon all bases, and that "Cost-Plus-a-Fixed-Sum" is not what its name implies unless the "Cost" *is* the cost, the *whole* cost, and *nothing but* the cost—and unless the *whole* of the "Fixed Sum" represents the *net* profit to the contractor.

Now let us turn to the three forms of contracts and consider their merits and disadvantages from the following standpoints:

1. Lowest total cost to the owner.
2. Greatest speed of construction.
3. Best workmanship.
4. Future business between owner and contractor, based on past experiences.

Under the "Lump Sum" contract the contractor agrees to furnish all labor and material necessary to complete a certain definite piece of work (plans, specifications and details of which *must be complete*) for a definite lump sum (or at unit prices, which means several lump sums). While at first glance that seems to be a very reasonable, harmless and peaceful contract, as a matter of fact, it is anything but that. The "Lump Sum" contract is a license to support lawyers and a privilege to pay court costs. You all well know what happens under the "Lump Sum" contract when the owner changes his mind and the architect changes his plans. That is what is called "Extra Work." That is what the contractor has been praying for; and from the time the first piece of extra work is ordered by the owner, that "Lump Sum" contract should be called by its real name, which is "The Lump Sum-Plus-Extra-Work-Plus-Time-Extension-Plus-Lawyers'-Bills" contract. In other words, the interests of the owner and the contractor are opposed from the start to the finish. Every cent that the contractor can save goes into his own pocket. Every cent the owner pays does not necessarily represent value received, inasmuch as the owner may be paying not only non-competitive prices for extra work, but also paying a large item for interest on his investment and for loss of rent because the work is not progressing any faster than the rate of speed of greatest economy to the contractor. Again, a little saving in the time taken for the riveting of the steel work, a little saving in the quantity of the cement used, or in the labor of mixing the concrete, while quite up to the requirements of the written specifications, is a saving to the contractor—not the owner. And these little savings, if undesirable or even if harmless, are savings that the contractor pockets, and for which the owner pays. Therefore the owner does not get his work done at the lowest cost, for he has agreed to pay the contractor a certain lump sum for performing a certain piece of work in such a manner that the owner and the architect cannot refuse to accept it. Without at this time discussing the question of the loop-holes in the "Lump Sum" contract—and the number of these loop-holes is legion—let us consider what the owner pays for this form of contract. The "Lump Sum" contractor will not work without a profit. Furthermore, he is taking the risk of unfavorable circumstances. He therefore adds a good stiff percentage so that he will be sure, no matter what happens, of making his profit. Generally the unfavorable circumstance does not develop and the contractor naturally pockets the difference saved. That means two profits. He also saves the money which may accrue through the fortunate circumstances which are just as likely to happen as the unfortunate ones. That would mean three profits.

Under the "Lump Sum" contract the owner cannot hold the contractor to the speed requirements nor to the date of completion of the contract if he has ordered extra work. There are certain well-known printed forms of contracts which have had an extensive sale which state that there shall be a time extension equal to the amount of delay caused by any extra work; and that particular clause has been a source of joy for many a hard-pressed contractor.

The second form of contract is known as the "Percentage" contract. Under this form, the contractor agrees to furnish all labor and materials necessary to complete the entire undertaking for cost, plus an agreed upon percentage of the said cost. This form of contract is very nearly perfect—but not quite. The owner can regulate the speed and the time of completion. He can decide whether or not he will give way to strikers or substitute non-union men. The interests of the owner and the contractor are identical so far as speed of construction and the desire to obtain good work are concerned. So far, the chances of continued pleasant relations would be good if it were not for the fact that the owner is apt to suspect that the contractor may be increasing the cost of the work for the sake of getting more profit, for the contractor's profit is, in this case, directly proportional to the cost of the undertaking. To obviate this disadvantage, the third form of contract, namely, the "Cost-Plus-a-Fixed-Sum" contract, was devised.

This "Cost-Plus-a-Fixed-Sum" form has all the advantages of the "Cost-Plus-Percentage" contract, without its one disadvantage, in that there is no incentive to the contractor to increase the cost, since it would not increase his profit. The only disadvantage that anyone can discover to the "Cost-Plus-a-Fixed-Sum" contract is that the owner cannot possibly get his undertaking completed for less than cost, as he might possibly do under the "Lump Sum" contract, if the contractor should make an error in his lump sum estimate and should have no opportunity to make up on "Extra Work." The advantages of this form of contract to the owner and to the contractor are numerous. The owner knows in advance exactly how much profit the contractor will make. The owner's interests require that the work be executed in the shortest possible time at the lowest possible cost and with the best workmanship. The owner's interests are absolutely identical with those of the contractor in every one of these particulars, because, his profit or salary being assured, the contractor's only interest is to perform the work in such a manner as to retain the owner's patronage. The owner is relieved of the menace of "Extra Work"—all the work being done at cost. The contractor's "Fixed Sum" is in no way affected by any changes in the plans. The owner has the benefit of all cash discounts for materials. The owner knows what all materials will cost before they are purchased. The owner himself can purchase the materials if he so desires. The owner can have his excavations and foundations completed while plans for superstructure are being drawn. The owner, engineer or architect can make changes and alterations at any time without delaying the work. The owner can have any number of skilled and carefully trained mechanics massed on his contract at a moment's notice. The owner knows from the very outset of the work what the contractor's profit is to be. It is the same amount, irrespective of the cost of the work, and there is therefore, no incentive for the contractor to produce anything but substantial and economical work. The owner has his building completed as rapidly as is consistent with good workmanship. The owner or his authorized representative has access at all times to all matters pertaining to the work.

The benefits of the "Cost-Plus-a-Fixed-Sum" contract, taken from the contractor's viewpoint, are: The contractor has the opportunity to win upon his merits an enviable position in the confidence of the business world. The contractor's profit on a piece of work is assured. The contractor will be free from relations with owners who have not the courage to take legitimate risks attendant upon their own enterprises, and who wish to saddle them upon a contractor on a lump sum basis and leave him to gamble his way out as best he can. The contractor has, on the other hand, the satisfaction of dealing with an owner who has no reason to suspect him of overreaching, who is not in constant dread of extortionate charges for "Extra Work," and who, in a word, has a contract offering complete insight to the financial affairs of the job.

While we never have claimed that we were the first concern to do contracting on the basis of "Cost-Plus-a-Fixed-Sum," we think that we were the first to start the campaign on "Cost-Plus-a-Fixed-Sum" and nothing but "Cost-Plus-a-Fixed-Sum;" a stand which we have taken as a result of our experience during the years that we took some "Lump Sum" contracts at the same time as we had "Cost-Plus-a-Fixed-Sum" contracts in operation.

We found that there was a tendency to put our best plant on the "Lump Sum" contracts, our best superintendents and our apprentices who could do a man's work for an apprentice's pay, and on the "Cost-Plus-a-Fixed-Sum" contracts the second-class foremen, "old pensioners" and the rest of the plant. To do away with this "tendency" we made it an iron-bound rule to take no more "Lump Sum" contracts under any conditions whatever, regardless of how much profit for us there might be in them. Moreover, we will not award a sub-contract for labor or material on the "Cost-Plus-a-Fixed-Sum" basis if the sub-contractor is handling any "Lump Sum" contracts at the same time.

One large firm advertises, "We take contracts on basis of actual cost, plus a fixed sum of profit to us, and for

*From a paper presented before the American Public Works Association.

†34 West 26th St., New York City.

this profit we furnish superintendents and complete plant." Now that *sounds* good to any inexperienced owner; but what is the "tendency?" Neither the "actual cash cost" nor the "fixed sum of profit" are what they are called if the contractor pays for the superintendence and also for the leasing of or for the deterioration of the plant. Then why not reduce the "Fixed Sum" and have the owner pay for *all* superintendence and *all* plant which may be leased, or bought new and sold at the completion of the work? He can then know just what he is actually getting and know what he is really paying for it. And furthermore, what is the "tendency" under *this* form of contract? Is it not perfectly evident that the less the contractor pays out of his fixed sum for superintendence and plant, the more he makes? The worst attempts to assassinate the "Cost-Plus-a-Fixed-Sum" principle are the advertisements which state, "We do work on the basis of cost-plus-a-fixed-sum-and-a-guaranteed-maximum;" also, "We take contracts on the basis of guaranteed maximum cost plus fixed profit to us."

Now at first glance, those do look as if they had all the advantages of the "Cost-Plus-a-Fixed-Sum" contract, and the "Lump Sum" contract combined, but they have nothing of the sort. On the other hand, they are absolutely nothing more or less than "Lump Sum" contracts (if they have a guaranteed maximum cost) and the "Fixed Sum" is "fixed" only in case the maximum is not reached.

The entire theory of the "Cost-Plus-a-Fixed-Sum" contract is that the owner shall have his own way in any and all matters pertaining to his work. He shall have the right to decide what materials shall be bought and whether or not they shall be bought of the lowest bidder. He shall have the right to order the contractor to put on as many or as few men as the owner wants, regardless of whether or not there are strikes. His decision shall be final regarding the paying of bonuses for the quick delivery of material, and his decision shall be final on all matters pertaining to the conduct of the job.

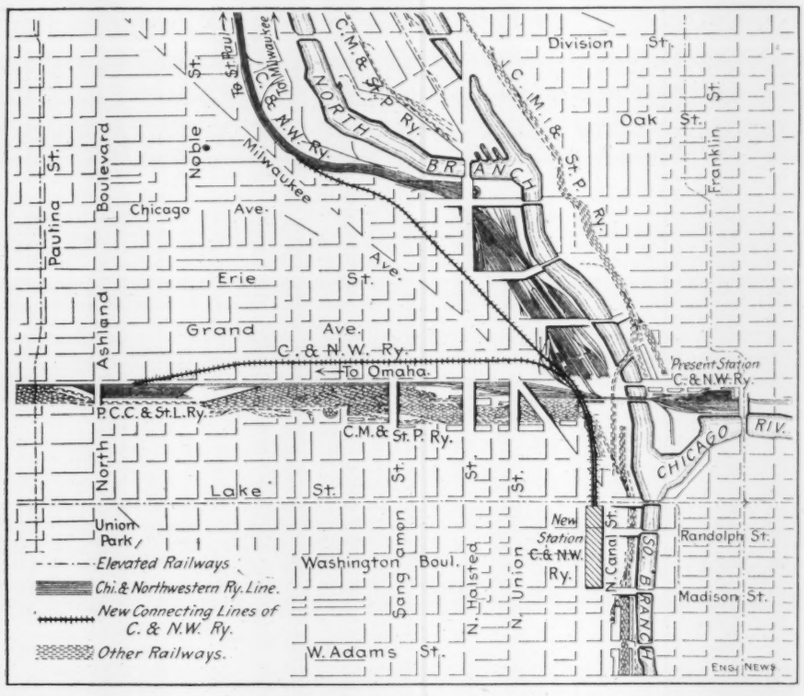
It is obvious that under these conditions it is ridiculous to expect any contractor to guarantee any maximum cost. If the "Cost-Plus-a-Fixed-Sum" contract is to be used, let the owner pay for *all* of the actual cash cost and have it understood how much actual profit the contractor is to have, and that *the entire "Fixed Sum" is to be net profit to the contractor.*

The "Cost-Plus-a-Fixed-Sum" contract has proved, time and time again, that the same amount of effort, thought and money, required to win lawsuits, can be better spent to reduce the costs and the time of construction and in securing better workmanship.

## A NEW CHICAGO TERMINAL FOR THE CHICAGO & NORTHWESTERN RAILWAY.

The Chicago & Northwestern Railway Co. is about to begin work on an elaborate passenger terminal improvement in Chicago, involving a new terminal station at some distance from the old, the construction of new connecting lines, the rearrangement of a considerable amount of yard-space, the acquisition and razing of about three dozen city blocks to provide space for the new tracks and for an industrial area, and the conversion of the present Kinzie St. terminal station into a freight depot. This project and the decision to carry it out have been the slow growth of some years, and solve the problem of a cramped terminal with a badly-throttled approach, not an uncommon problem in railways, but of rather aggravated nature in the case of the Northwestern's Chicago terminal. A brief note of the new terminal plans—which have been developed in absolute secrecy during the past year—was given in our last issue, and we are now able to supplement this with a map of the district affected, which will show the principal features of the projected work.

The map herewith shows a portion of Chicago lying immediately west of the line of the North and South Branches of the Chicago River. The business district of the city is in the restricted area south of the Chicago River and east of the South Branch, an area about ½-mile wide east and west by ¾-mile long. The present passenger terminal of the Chicago & Northwestern Ry. lies at Kinzie and Wells Sts., just north of the Chicago River and east of the North Branch. It is reached from the center of the city by way of a drawbridge on the line of Wells St. and Fifth Ave., carrying surface cars and a double-track elevated railway. As the Chicago River has a heavy vessel traffic, the route to the station over the Fifth Ave. bridge is at all times liable to involve annoying delay by the passage




MAP OF PART OF THE CITY OF CHICAGO, ILL., SHOWING NEW TERMINAL STATION AND APPROACH LINES OF CHICAGO & NORTHWESTERN RAILWAY.

of vessels through the bridge. A more circuitous alternative route is by way of a tunnel under the Chicago River at La Salle St., one block east of Fifth Ave; but as this is less convenient, it is very little used for travel between the business district and the Northwestern Station, so that virtually the station is reached from the south by only a single crossing.

While the present station is thus rather unfavorably situated with regard to accessibility from the city, its relation to the prompt movement of trains is much more important. And here is perhaps the most serious disadvantage of the present location, and the immediate motive that led to the adoption of the project for a new terminal. About 400 trains daily, regular and suburban, use the Northwestern terminal. Three divisions enter the terminal (no other railway uses the Northwestern station, in which respect the station is unique among the Chicago railway depots), respectively from the north (Milwaukee, Wis.), the northwest (St. Paul, Minn.) and the west (Omaha, Neb.). The Milwaukee and St. Paul lines join at Clybourne Junction, some two miles northwest of the terminal, and continue south to West Kinzie St. as a single four-track line, while the Omaha division runs east along West Kinzie St. as a four-track line; at the west bank of the river the two trunks run together, and cross to the station by way of a double-track drawbridge over the North Branch of the river. This bridge forms a contracted throat at the very entrance of the station, and as the vessel movement on the North Branch seriously cuts down the normal capacity of the bridge, the latter limits the capacity of the entire terminal plant.

The present terminal suffers under the further disadvantage that it is so located that enlargement is practically impossible. There was thus no possibility of even temporary relief of the operating difficulties of the terminal by increasing the station trackage. A new location for the terminal, so selected as to give better facilities of access, greater capacity, and approach tracks not complicated by bridge crossings and the like, was the logical necessity. The present plans of improvement provide for these desiderata.

The new terminal station, as the map shows, is located west of the river, so that the movement of trains is not subject to interruption by river traffic. The station fronts on Madison St., in the block from Canal to Clinton, diagonally opposite the Union Station (the passenger terminal of the Pennsylvania, the Chicago & Alton, the Chicago, Milwaukee & St. Paul, and the Chicago, Burlington & Quincy railroads). The point has numerous routes of communication with the business district of the city as well as with the regions north, west and south. A number of street bridges and one street tunnel, all carrying electric car lines, and two elevated railways having independent river-bridges, afford alternative means for reaching the station from the east side of the river.

The new station is planned to be three blocks long, so that the platform tracks and their extensions will accommodate 12 to 16 cars each; it will be 16 or 17 tracks wide, and its total capacity will be not far from 200 cars. The station and its approaches are elevated.

A not inconsiderable part of the difficulties in the way of the present solution lay in the approaches; the final location of the connecting lines is shown on the map. The existing Omaha line is elevated to the full height from Ashland Ave. westward, and eastward from Ashland Ave. it drops to the grade of Ada St. From this point into the present station, Sangamon, Halsted, Desplaines Sts. and Milwaukee Ave. are carried over it on viaducts, but grade crossings now exist at the intermediate streets—that is, such of them as are open to traffic. It is generally four tracks wide and is parallel to the P. C. & St. L. and the Chicago, Milwaukee & St. Paul roads to a point where the latter tracks curve southward into the present Canal St. Station, situated on the west side of the south branch of the Chicago River between Madison St. and Jackson Boulevard and east of Canal St.

The Northwestern, in order to reach the site of the new station, found it necessary to do so on an elevated structure to eliminate all grade crossings of either streets or other railway lines. This is accomplished by branching off of the present Omaha line just east of Ashland Ave. and swinging north to a parallel location immediately south of the south line of Austin Ave. on an elevated structure, keeping far enough away from existing viaducts to cross the streets leading thereto at the foot of the approaches. East of Milwaukee Ave. the line curves southward, crossing over the present Omaha line, the

Chicago, Milwaukee & St. Paul and the P. C. & St. L. at Clinton St., the connecting line being a four-track elevated structure, crossing the streets on steel bridges with a minimum clearance of 14 ft. above the roadways, the intermediate portions between the street lines being constructed on an embankment to be confined by masonry retaining walls.

The trunk carrying the Milwaukee and St. Paul divisions is treated in substantially the same manner. These divisions run along the west shore of the North Branch, spreading out into large yards, and finally curving eastward to a junction with the Omaha line at Kinzie St. just west of the drawbridge leading to the present terminal station. The connection to the new station, which, like the Omaha connecting line, is four tracks wide, diverges somewhat westerly from the present line near Elston Ave., and rises to cross intervening streets and tracks, and reach the grade of the new station. The last quarter mile it is parallel to the Omaha line, but the two trunks are kept separate up to the entrance to the station tracks, where they are drawn together to a six-track throat at Lake St.

At Lake St., where the line of the Lake St. Elevated Ry. is crossed, conditions are such as to require raising the Lake St. structure in order that the tracks into the terminal station may pass underneath with proper clearance. The amount of this raising approximates 6 ft., tapering off to zero at the bridge by which the Lake St. Elevated crosses the river. The crossing over the six tracks will consist of a single plate-girder span of about 100 ft.

The new location in the case of both lines passes for the most part centrally through the blocks of a solidly built-up factory and business district. The plan involves the purchase of all the property between the new and the present locations, to facilitate a free rearrangement of yards, and the thorough exploitation of the present locations as freight terminals. Practically all of this real estate is already held by the railway, having been bought up under cover during the past year.

It is probable the areas between the new entrance immediately south of Austin Av. and the present tracks will be devoted entirely to the establishment of industries desiring railroad track connections, very materially adding to the ability of the railroad company to increase its terminal freight business by affording locations with convenient track connections in the heart of the city. To increase freight facilities by the utilization of that portion of the terminal now devoted to passenger facilities and a still greater expansion afforded by the areas between the old and new lines is one of the most valuable features of the new project.

This terminal improvement project has been promoted mainly by Mr. Marvin Hughitt, President of the Chicago & Northwestern Railway Co. About a year ago Mr. Hughitt associated with him as his confidential consulting engineer Mr. John F. Wallace, formerly Chief Engineer of the Panama Canal and now President of the Electric Properties Co., of New York, N. Y. The project as here outlined was worked out by these two men jointly. The execution of the project will be in the hands of Mr. Edward C. Carter, Chief Engineer of the company. The entire work will cost about $20,000,000 and will require about two years to complete.

## NOTES FROM ENGINEERING SCHOOLS.

UNIVERSITY OF COLORADO.—At a recent meeting of the Regents of the University, the name of the engineering department of the University was changed from the "School of Applied Science" to the "College of Engineering," and Professor M. S. Ketchum, formerly dean of the School of Applied Science, was made dean of the College of Engineering.

INTERNATIONAL CORRESPONDENCE SCHOOLS.—The fifteenth anniversary of the founding of these schools was celebrated at Scranton, Pa., on Oct. 16. Several hundred guests were present, including representatives from many of the leading colleges and Universities. A report of the anniversary exercises is necessarily postponed to our next issue.

PURDUE UNIVERSITY. — The following changes have taken place in the faculty of the Engineering Department since last year: Prof. W. K. Hatt, Ph. D., formerly Professor of Applied Mechanics, has been made Professor of Civil Engineering in charge of the Department; Mr. Paul N. Brenemab, B. S., C. E., State College of Pennsylvania, formerly Engineer and Superintendent of Mining Construction and Operation, has been made Instructor in Civil Engineering; Mr. Arthur W. Cole, B. S., Worcester Polytechnic Institute, formerly of the University of Maine, has been made Instructor in Thermodynamics; Mr. L. W. Wallace, B. S., Texas Agricultural and Mechanical College, late with the Motive Power Department of the Santa Fe Railroad, has been made Instructor in Car and Locomotive Design; Mr. W. T. Small, B. S., Purdue, formerly with the Cooper-Hewitt Electric Co., has been made instructor in the electrical laboratory; Mr. C. E. Schutt, B. S., Purdue, formerly with the New York Telephone Co., Mr. George W. Lamke, B. S., University of Michigan, and Mr. W. A. Rush, B. S., Purdue, have been made assistants in the electrical laboratory; Mr. R. D. Kneale, B. S., Purdue, and Mr. M. L. Allen, B. S., University of Wisconsin, have been made assistants in the civil engineering department.

EXCAVATION FOR THE PANAMA CANAL in the Culebra Cut on the Isthmus, during the months of August and September, exceeded that of any previous month since the American control of the work. According to recent reports from the Chief Engineer of the Isthmian Canal, the amount excavated in August was 244,844 cu. yds., which was 5,666 cu. yds. more than the total of the heaviest previous month, March, 1906. In September the amount was 289,000 cu. yds., or 45,000 more than in August. There was available at the end of August a total force of 46 steam shovels, of which 27 were at work in the canal prism, four on the Panama Railroad, two outside the prism, and the others set up and ready for work in various places. The double-tracking of the Panama R. R. is going forward steadily. Of the 35 miles of additional track contemplated, about 15 miles have been completed, and are ready for use, and about 10 miles more are ready for track laying and ballasting, or about 75% completed. The receiving and forwarding yards which are to serve as the great clearing-house for trains of spoil from the Cut are partly completed at Pedro Miguel and Las Cascadas, and the yard at La Boca is about 75% completed.

ELECTRIFICATION of a steam railway line is very expensive work, particularly when the work is done on the passenger terminal of a trunk line railway in a great city. The New York Central & Hudson River R. R. Co. has just been authorized to increase its capital $100,000,000 on account of its terminal improvements at New York City now in progress. Previous to this increase its total capital stock was only $150,000,000. At the hearing before the State Railroad Commission, when this increase of capital stock was authorized, officers of the company stated that the reconstruction of the New York terminal and suburban lines and their equipment with electric traction will absorb the greater part of the money raised by this new stock issue.

A BAD RAILWAY WRECK occurred at Epernon, Department of Eure-et-Loir, France, Oct. 14, in which 12 persons were killed and 50 injured, 15 of whom are not expected to live. A passenger train was standing at the station, when a locomotive traveling at a high rate of speed, crashed into it, smashing four coaches. No cause for the accident is given in the press reports.

A COLLISION of Hudson River steamboats, near Tivoli, N. Y., Oct. 13, resulted in the death of one person and the injuring of several others. The collision was due to a heavy fog. The iron steamboat "Adirondack" of the People's line, on its way to Albany, N. Y., struck the wooden steamboat "Saratoga" of the Troy line, bound for New York, a glancing blow on the port side, directly in front of the wheel-house, tearing off the wheel-house, and after portion of the main deck's siding, smashing the paddle-wheel and knocking the port boiler into the river. The force of the collision threw several passengers into the water, but they were soon rescued. The passengers of the "Saratoga" were transferred to other river craft, which came to her assistance, and landed at Tivoli and Hudson, N. Y. The "Saratoga" was beached, while the "Adirondack," being but little damaged, proceeded on her way north, after those who desired it had been transferred to other boats to be landed.

THE BURNING OF THE BRITISH STEAMSHIP "Hankow" at her wharf at Hongkong, British China, Oct. 14, resulted in the death of over 1,500 Chinese steerage passengers. The boat had but just made fast to her pier when she was discovered to be on fire, and, before the fire pumps could be turned on, all escape for the steerage passengers was cut, while the few European cabin passengers escaped with difficulty. The "Hankow" carried a cargo of matting, raw silk and other inflammable material. The fire is thought to have been of incendiary origin, as the Chinese had declared a boycott against British river boats.

AN OLD FOOTBRIDGE FAILED at Oconto, Wis., on Oct. 5. The bridge, at Oconto Falls, was known to be weak, and when a field-party of 25 high-school students, under the guidance of an instructor, desired to go on the bridge they could not obtain permission to do so until they agreed to divide into two sections, only one of which should be on the bridge at a time. The second section was on the bridge when it collapsed. One of the students was killed.

A FIRE in the south tube of the Pennsylvania tunnel under the East River, Oct. 11, resulted in the suffocation of three men by smoke. Laborers in the heading discovered the telephone booth to be on fire and immediately left the lock and gave the alarm. Thereupon two foremen and a lock tender entered the lock with the intention of fighting the fire, but they were quickly overcome by the smoke, and by the time the rescuers had forced an entrance to the lock they were dead. The damage done by the fire was nil. Many of the rescuers were overcome by the smoke, but were quickly revived.

A 285-MILE PIPE LINE, for carrying oil, is to be built from Pine Grove, W. Va., to Marcus Hook, Pa., by the Pure Oil Co., according to press dispatches. The line will be laid with 6-in. pipe, and its estimated cost is $1,000,000. Marcus Hook lies about 17 miles southwest of Philadelphia.

THREE WARSHIPS of greater offensive power than the battleship "Dreadnought" are being built by the British Government, according to the London press. These ships, the armored cruisers "Inflexible," "Indomitable" and "Elswick," it is said, will have as heavy a broadside fire as the "Dreadnought" and a greater speed. A comparison of these cruisers and the "Dreadnought" follows:

| | Dreadnought. | Cruisers. |
|---|---|---|
| Speed | 21 knots | ? |
| Length | 520 ft. | 530 ft. |
| Breadth | 82 ft. | 78½ ft. |
| Mean draft | 26½ ft. | 26 ft. |
| Displacement | 18,000 tons | 17,250 tons |
| Main battery | ten 12-in. guns | eight 12-in-guns |

As is seen from the table, the cruisers have two fewer guns than the "Dreadnought," but this is compensated for, according to reports, by their arrangement, four in two barbettes fore and aft, with a training arc enabling them to be used one either side, and four more in two barbettes placed en echelon in the center of the ship so as to bear on either beam, which gives a broadside of eight 12-in. guns, the same as the "Dreadnought."

A DOUBLE-TRACKED STEEL RAILWAY BRIDGE, about 2 miles long and said to be the longest two-track steel railway bridge in the world, is being built across the Columbia River, near Portland, Ore., by the Portland and Seattle Ry. (a new railway which is backed by James J. Hill). The same company is also building a bridge across the Willamette River, Ore., which will have a draw-span between 500 and 600 ft. long, and claimed to be the longest in the world. This is the first time that attempts have ever been made to bridge the Columbia River so near its mouth.

THE ANNUAL POSTAL DEFICIT, for the fiscal year ending June 30, 1906, was $10,516,995.95, or a reduction of more than $4,000,000, or 27.83%, over the previous year. The total receipts for 1906 were $167,932,762.95, an increase of $15,105,197.85 over the year 1905. This is the greatest increase of any year in the history of the service, and equals 9.83%. The total expenditures for the year were $178,449,778.89, an increase of $11,050,609.66 over 1905.

THE HEIGHT OF STREET CAR STEPS must not be more than 17 ins. above the top of the track rail. This conclusion was arrived at by a committee appointed by the Street Railway Association to consider the complaints received from time to time by the New York State Board of Railroad Commissioners from women users of cars in regard to the excessive height at which car steps are placed. The committee's report was handed to the Street Railway Association in convention

at Albany, on Sept. 19, and a maximum height of 17 ins. for the street surface roads in this state was adopted. Another matter discussed was the brake equipment of electric cars, especially suburban cars operated on roads with heavy grades. The committee of the state association appointed to consider this matter reported that double-chain brakes on electric cars were not an additional safeguard, as the idle chain picks up obstructions and prevents the operation of the braking system. A special committee was therefore appointed by the association to report upon a standard braking system for the different classes of cars.

A MONORAIL RAILWAY on the system invented by H. H. Tunis, of Baltimore, Md., is to be operated at the Jamestown Exposition. There is an overhead steel structure which keeps the car from tipping over, and the usual claims of extraordinary speed are made for the system.

## PERSONALS.

Dr. John McGaw Woodbury has resigned as the head of the Street Cleaning Department of New York City.

Mr. W. A. Whitney has been appointed Superintendent of the Rio Grande Junction Ry., to succeed Mr. W. G. Choate, resigned.

Mr. Tracy Lyon has resigned as Assistant General Manager of the Chicago Great Western Ry., and the office has been abolished.

Mr. J. C. Fitterer has resigned as Assistant Engineer in the U. S. Reclamation Service to accept a position at Glenwood Springs, Colo.

Mr. Charles C. Cochran has been appointed Assistant Professor of Mechanical Engineering at the University of Kansas. He is a graduate of the University of Colorado.

Mr. Rich G. Doerfling has resigned as Engineer in the U. S. Reclamation Service to become connected with the engineering staff of the Trussed Concrete Steel Co., of Detroit, Mich.

Mr. Rudolph P. Miller, M. Am. Soc. C. E., formerly Chief Engineer, Bureau of Buildings, New York City, has opened an office at 527 Fifth Ave., New York City, as a consulting engineer.

Mr. Edgar Van Etten has been elected President of the Long Acre Light & Power Co., of New York City. Mr. Van Etten is Vice-President of the New York Central lines, in charge of the Boston & Albany R. R.

Mr. T. Roberts, Chief Mechanical Engineer of the South Australian Government, has been appointed Consulting Mining Engineer for the whole of Australia, by the Australian Commissioner of Railways. His headquarters will be in London.

Mr. A. S. Zinn, M. W. Soc. E., formerly Construction Engineer for the Michigan Central R. R. at St. Thomas, Ont., has accepted the position of Resident Engineer on the Panama Canal. Mr. Zinn was Principal Assistant Engineer of the Chicago, Rock Island & Pacific Ry. before going to the Michigan Central R. R.

The following changes have taken place in the personnel of the Reclamation Service: Mr. W. P. Hardesty, Assistant Engineer on the Shoshone Project, Wyo., Mr. Harold M. Morse, Engineering Aid, in charge of hydrographic investigations in Montana, and Mr. Charles H. H. Stone, Assistant Analyst in the laboratory for testing materials, St. Louis, Mo., have resigned from the service.

Mr. Michael Jenkins, of Baltimore, Md., formerly Vice-President, has been elected President of the Atlantic Coast Line R. R. to succeed Warren G. Elliott, deceased. Mr. Waldo Newcomer has been elected Vice-President, while the directors are as follows: Mr. Henry Walters, Mr. Michael Jenkins, Mr. Waldo Newcomer, Mr. Warren Delano, Jr., Mr. Alexander Hamilton and Mr. N. J. James.

Mr. Henry M. Payne, Civil and Consulting Engineer, Williamson, W. Va., has been elected General Superintendent and Chief Engineer of the Mingo Block Coal Co., and will assume control of the company's business on Dec. 1. His present offices in the White Building will be retained by the Coal Company as its headquarters. The engineering force now employed by him will also be retained by the Coal Company.

Mr. Cecil B. Smith, Chairman of the Temiskaming & Northern Ontario Railway Commission, has resigned to take charge of the construction of a 60,000-HP hydro-electric plant on the Red River for the City of Winnipeg, Man. Mr. Smith had charge of the erection of the Canadian Niagara Power Co.'s plant at Niagara Falls, and was formerly Secretary of the old Canadian Power Commission. When this Commission was superceded by the new Hydro-Electric Power Commission he was made a member of the latter, and still retains his membership. He is a graduate of McGill University, and, after spending some years in railroad building, was made Assistant Professor of Engineering at this institution. From 1895 to 1901 he was Assistant City Engineer of Toronto, Ont., when he was placed in charge of the construction of the Niagara Falls power plant.

The following is a list of the engineers of the grade of Assistant Engineer and higher now in the service of the Isthmian Canal Commission:

OFFICE OF CHIEF ENGINEER.—Chief Engineer, John F. Stevens; Assistant Chief Engineer, John G. Sullivan; Office Engineer, W. J. Karner.

DIVISION OF METEOROLOGY AND RIVER HYDRAULICS.—Division Engineer, Ricardo M. Arango.

MECHANICAL DIVISION.—Superintendent of Motive Power and Machinery, George D. Brooke; Mechanical Engineer, Earle J. Banta; Master Mechanics, E. C. Cummings, E. G. Harrington, W. J. Thomas; Electrical Engineer, A. L. Robinson.

MUNICIPAL ENGINEERING.—Division Engineer, J. G. Holcombe; Resident Engineers, H. P. Linnell, H. W. Durham; Assistant Engineers, G. V. Barril, F. R. Bartles, Chas. W. Beattie, W. M. Acheson.

CULEBRA DIVISION.—Resident Engineers, A. B. Nichols, W. B. Ruggles; Assistant Division Engineer, D. W. Bolich; Assistant Engineers, R. W. Hebard, A. Raggi, O. F. Lackey, M. W. Tenny, W. F. Griffith, G. S. Walsh, R. B. Manter, Frederick Mears.

LA BOCA DIVISION.—Division Engineer, William Gerig; Resident Engineer, A. C. Harper.

COLON AND CRISTOBAL DIVISION.—Division Engineer, F. B. Maltby; Resident Engineer, W. B. Comber; Assistant Engineer, H. K. Higgins.

CHAGRES DIVISION.—Resident Engineer, C. L. Carpenter; Assistant Engineers, G. M. Wells, John Hayes.

BUILDING AND CONSTRUCTION DIVISION.—Assistant Engineer, W. H. Farrington.

DIVISION OF GATES AND LOCKS (located in Washington).—Principal Assistant Engineer, Joseph Ripley; Assistant Engineer, M. G. Barnes.

### Obituary.

Sir Richard Tangye, head of the engineering firm of Tangyes, Birmingham, London, Johannesburg, Sydney, etc., died at London, Oct. 14, aged 73 years.

R. B. Borden, Treasurer of the Richard Borden Mills and the Troy Cotton & Woolen Manufactory Co., died at Fall River, Mass., Oct. 12, aged 72 years.

A. H. Knapp, President of the Passaic Rolling Mill Co. and the Passaic Steel Co., died at Paterson, N. J., Oct. 12, aged 46 years.

John E. Powell, President of the Pittsburg Light & Manufacturing Co., Pittsburg, Pa., died at West Middlesex, Pa., Oct. 6, aged 40 years.

G. M. Farley, Resident Engineer of the Western Division of the Southern Pacific, was killed near Mikon, Cal., Oct. 10, by falling from a train.

Clarence B. Riggs died at New York City, Oct. 14, of injuries received in an explosion. He was a graduate of Norwich University and was employed as a civil engineer by the Interborough Rapid Transit Co. He was formerly connected with the New Rochelle Water Co. and the Deep River Co., of Connecticut.

Richard Morgan, formerly Superintendent of the Allison Drydock Co., died at Jersey City, N. J., Oct. 11, of pneumonia, aged 81 years. Mr. Morgan was born in England, but removed to the United States when ten years of age. In 1854 he set up a drydock at the foot of Morgan St., Jersey City, which eventually developed into the Allison Drydock Co.

## ENGINEERING SOCIETIES.

### COMING MEETINGS.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION.
Oct. 15 to 19. Annual Convention at Columbus, Ohio. Secy., Bernard V. Swenson, 60 Wall St., New York City.

AMERICAN GAS INSTITUTE.
Oct. 17-19. First Annual Meeting at Chicago, Ill. Acting Secy., James W. Dunbar, New Albany, Ind.

ROADMASTERS' AND MAINTENANCE OF WAY ASSOCIATION OF AMERICA.
Nov. 13-15. Annual Meeting at Chicago, Ill. Secy., C. E. Jones, Beardstown, Ill.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 3-4. Annual Meeting at New York City. Secy., W. Everett Parsons, 12 Bridge St., New York, N. Y.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 4-7. Annual Meeting at New York City. Secy., F. R. Hutton, 12 West 31st St., New York, N. Y.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec 27-Jan. 2, '07. Annual Meeting at New York City. Secy., L. O. Howard, Cosmos Club, Washington, D. C.

THE CONCRETE ASSOCIATION OF NEW YORK.—The regular October meeting of the Association will be held in the rooms of the Building Trades Employers' Association, 1123 Broadway, Oct. 19, at 8 p. m. This will be a business meeting for the election of a nominating committee, and for making final arrangements for Mr. Humphrey's lecture Oct. 24. (Engineering News, Oct. 4, 1906, p. 366.)

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.—The regular monthly meeting of the Society was held Tuesday evening, Oct. 16, in the Society's rooms. Saturday afternoon, Oct. 20, the Society will make an excursion to the Carnegie Technical Schools, Pittsburg, Pa., while an all-day excursion will be held Oct. 27 to Conneaut Harbor, Ohio, the party leaving Pittsburg by a special train over the Bessemer Railroad.

TECHNOLOGY CLUB OF SYRACUSE.—The annual meeting of the Club was held Monday evening, Oct. 8. After routine business had been completed Mr. Henry C. Allen read a paper, illustrated with stereoptican views, on "Special Machinery Used in Connection with the Barge Canal Contracts." The following officers were elected: President, Mr. John H. Barr; First Vice-President, Mr. Edward N. Trump; Second Vice-President, Mr. H. H. Crowell; Directors, Mr. Edward P. Bates, Mr. Geo. G. Fryer, Mr. Paul C. Nugent and Mr. F. J. Schnauber; Secretary, Mr. Geo. D. Babcock; Treasurer, Mr. Frank G. Chambers.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.—The thirteenth annual convention of the Society, held last week in Birmingham, Ala., was one of the best in its history. The attendance from the North was good, and nearly all the Southern states were represented. Members were elected from the two Carolinas, Georgia, Alabama, Louisiana, Texas and Missouri, as well as from many Northern states, a total of 48 being elected. Many excellent papers were read, the one of most interest to the Southern people being that on "Yellow Fever and Sanitation," by J. N. Hazlehurst, of Mobile, Ala. This paper told in what way and with what degree of success the campaign against the mosquito had been carried on in the South. The results given proved conclusively that systematic efforts to get rid of this pest will be well rewarded. A paper, by Geo. G. Earl, General Superintendent of the Sewerage and Water Board of New Orleans, La., described in detail and very interestingly the work that is being carried on by that Board. The paper was profusely illustrated by lantern slides. On Wednesday the city tendered to the visitors a drive over the mountains to visit the water-works, supplementing it with an old-fashioned barbecue near the filter plant. On Thursday the Society, by means of a special train, visited many of the mineral and other industries of Birmingham, seeing at one place a mill where iron ore is taken in at one end and delivered at the other in the form of steel railroad rails. The party was much impressed with the vast resources of the Birmingham district. The following officers were elected for 1907: President, M. R. Sherrerd, of Newark, N. J.; First Vice-President, James Owen, Montclair, N. J.; Second Vice-President, Julian Kendrick, Birmingham, Ala.; Third Vice-President, Fred Giddings, Atchison, Kan.; Secretary, Geo. W. Tillson, Brooklyn, N. Y.; Treasurer, Leslie V. Christy, Wilmington, Del. The next meeting of the Society will be held in Detroit, Mich., in October, 1907.

ILLUMINATING ENGINEERING SOCIETY.—The October meeting of the society was held in the Edison Auditorium, 44 West 27th St., New York, Friday evening, Oct. 12, 1906. About 45 were present. The meeting opened with a statement from the secretary, Dr. A. H. Elliott, which showed the society to have a balance of $586 on hand, and a membership of 750. The President, Mr. L. B. Marks, then named a committee to nominate certain temporary officers for the New York section, to tide over until the regular election in January. The vacancies filled and the members elected thereto were as follows: Chairman, Mr. A. E. Forstall; First Vice-Chairman, Mr. F. A. Patterson; Second Vice-Chairman, Dr. F. Schieman; Secretary, Mr. Preston S. Miller. Two papers were presented: One entitled "Application of Photometric Data to Indoor Illumination," by Mr. Ernest C. White, Illuminating Engineer, Winnipeg, Manitoba, and the other, "Data on Indoor Illumination," by Mr. J. S. Woodwell, Inspector of Electric Light Plants, U. S. Treasury Department. The discussion which followed the reading of the papers was taken part in by Mr. E. L. Elliott, who suggested a remedy for the poor system of lighting in the newspaper room of the Congressional Library, which matter was brought up in Mr. Woodwell's paper. His recommendation was that a portion of the lamps be placed on the reading desks instead of all of them being mounted on the ceiling. Dr. A. H. Elliott stated he had found that plaster of Paris when clean and pure reflected 80% of the light falling on its surface, and suggested in cases where this material was exposed, to let the light rays strike it directly and be reflected and diffused instead of cutting down at the lamp the light we had taken so much trouble to produce. Mr. Gardner asked why people required a higher degree of illumination in their homes at the present time than they did 10 or 15 years ago. Why three or more lights are now used when formally one sufficed. Dr. Sharp answered the question by saying that people's tastes had been toned up by the higher degree of illumination used in public places, and, becoming accustomed to the stronger light, demanded it in their homes.

# ENGINEERING LITERATURE

Supplement to ENGINEERING NEWS. New York, October 18, 1906.

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## REVIEWS.

### Steam Turbines.

Reviewed by Storm Bull.*

STEAM TURBINE ENGINEERING.—By T. Stevens, A. M. Inst. C. E., A. M. I. E. E., and H. M. Hobart, M. I. E. E., Mem. A. I. E. E. New York: The Macmillan Co. London: Whittaker & Co. Cloth; 6 × 9¼ ins.; pp. 814; 516 figures, mostly in the text, and 150 tables. $6.50.

STEAM TURBINES AND TURBO-COMPRESSORS.—Their Design and Construction. By Frank Foster, M. Sc. Manchester, Eng.: The Scientific Publishing Co. Cloth; 6½ × 8¾ ins.; pp. 449; 249 figures in the text, and 66 tables. 10s. 6d., net; American price, $4.20, net.

The author of each of these books states in his preface that he feels that there is need for the special kind of book which he has brought out. To the reviewer it would appear that the literature on the subject of Steam Turbines is very far from being complete as yet, so that there is room for a good many books, provided they are of the right kind. Looking at it broadly it must be admitted that each book is a welcome addition to technical literature, although the character of the two books is very dissimilar.

"Steam Turbine Engineering" has been written, as stated in the preface, expressly for the purchasers of turbines, to aid them in the selection of such, or, perhaps more properly, to help them to decide whether to purchase reciprocating engines or turbines, and, if they decide on turbines, then to guide them in their selection. The scope of the book goes, however, much farther. It is, for instance, certain that it will be found very useful to all engineers who are to design power plants, especially because of the large number of good illustrations of such plants, accompanied by detailed information as to machinery and boilers used and results obtained. It is to be noted that only those plants are described in which there is at least one steam turbine.

In another respect this book will be found very useful to the practicing engineer, and that is in the abundant material it furnishes for the comparison of the economic results obtained with reciprocating engines and turbines. The authors have brought together a wealth of data that cannot be found in any other single book. To an American engineer it may perhaps be objectionable that the results, so far as reciprocating engines are concerned, have principally been taken from European practice. The authors seem to show, as has also been assumed by most engineers, that there is very little if any difference in the steam economy of the turbine and the reciprocating engine (beyond a certain size, at least), and it is evident that the authors do not expect to see the steam turbine develop much more rapidly in this respect than the reciprocating engine—at least in the near future. It is probably needless to say that the authors point out that other circumstances besides steam economy may determine the choice between the two.

The first 340 pages of the first-named book contain excellent descriptions of all the best-known steam turbines and in the following order: De Laval, Parsons, Curtis, Rateau, Zoelly, Riedler-Stumpf, A. E. G., Hamilton-Holzwarth, Elektra and the Union. They are all accompanied by very good illustrations and with a very large number of tables and curves giving the dimensions of and the results obtained with various sizes of the turbines in question. These results have partly been obtained from the manufacturers and partly from tests conducted by independent parties. Authorities are quoted everywhere, so that it is possible to judge as to the weight to be given to such tests and to look up their authenticity. The De Laval and Parsons turbines are given the most space, probably both because these two were the pioneers and because a larger number of each kind are at present in service than of any other kind.

In discussing the results obtained with Parsons turbines the authors have come to the conclusion that the steam economy for these turbines is nearly independent of the steam pressure, provided that it be between 7 and 14 metric atmospheres, or say 100 and 200 lbs. per sq. in. Such a conclusion is rather startling, but the authors seems to sustain it with ample experimental evidence. As it takes more heat to produce steam at say 150 lbs. than 100 lbs. pressure the further conclusion should be drawn that no higher pressure than 100 lbs. should be used for Parsons turbines. The reviewer must, however, admit that he is rather sceptical as to the correctness of the conclusion drawn; not so far as the available material is concerned, but in assuming that the various turbines, the tests of which seem to warrant this conclusion, have been designed with equal care or knowledge for the various pressures at which they were to be run and at which they were tested. To the reviewer there seems to be no inherent reason why the steam economy of the turbine should not increase in about the same manner as that of the reciprocating engine—with increasing pressure. If the results of the economy tests of the engines and turbines had been stated in B. T. U. per KW.-hr. or per HP.-hr., then it would have been at once apparent that the conclusion of the authors inevitably lead to the further conclusion already stated: that no higher pressure than 100 lbs. should be used for Parsons turbines. As the results in the book are stated in kilograms per KW.-hr., this was not so apparent, which again shows that the results of economy tests of all heat motors should be expressed in heat units consumed per HP.-hr. or per KW.-hr. It is to be noted that notwithstanding this is an English book the metric system of units has been used throughout, the results of American and English tests and the dimensions of turbines, etc., from these countries having been transferred to the metric system. It is evident from this that they dare to go farther in that line in England than in the United States.

In order to further show the usefulness of the book the headings of chapters 15 to 21, inclusive, will here be given: "Typical Results as to Steam Economy in Modern Piston Engines," "Mean Representative Results for Steam Turbines and Comparison with Results for Piston Engines," "Steam Pressure, Superheat and Vacuum in Plants in Operation," "Condensers," "Foundations," "Buildings," "Boiler and Super-heater Surface Installed." Chapter XXIII. treats of marine steam turbines, and it contains both excellent descriptions and illustrations of such installations, as well as the best compilation of results of economic tests of these as far as the reviewer knows. Chapter XXIV. is a bibliography of the subjects treated in the book referring to the steam turbine, and is without question the best and most complete so far published; in fact, it is very much superior to any other. From what precedes it is evident that Stevens and Hobart's book should be recommended to all interested in steam turbine engineering. The only other criticism which might be passed is that a chapter on "a recapitulation of the properties of steam" and another on the "calorific value of fuels" does not belong in a book of this character. Any one who is to use the book with profit should be perfectly familiar with the above subjects. The book is excellently gotten up, both as to paper, printing and illustrations.

Mr. Foster's book is, as stated above, of a very different character, and, let it be said at once, not of nearly as much importance. But nevertheless, with other books published during the last year or so in this country, it fills a want which all those who are interested in the subject of steam turbines should be grateful to see supplied. When, however, the author states in the preface that "most of the subject matter in this book is original," the reviewer must at once take exception. The book contains some valuable original contributions to the literature on the subject, but of necessity its major portion must consist of material which is found elsewhere, although perhaps in scattered form. It is not quite apparent from the preface for what class of persons this book has been written; but from the book itself it would seem evident that it was meant especially for those who have to do with the designing of steam turbines; and perhaps, secondly, to be used as a text book. And it is likely that it will be found useful in both directions.

The first chapter treats of Types of Turbines. In it the author very clearly explains the fundamental differences between the so-called "reaction" and "impulse" turbines. In the second chapter will be found descriptions, accompanied by illustrations, of a number of the best-known turbines. The list is not nearly as complete as the one in the book first reviewed, nor are the illustrations as good, most of them being "pictures" of comparatively little value to the designer, and nearly all reproduced from other recent books on the steam turbine. Steam nozzle and disk friction form the subject of the third chapter, on which subjects, however, very much more information may be found in Stodola's book, reviewed some time ago in these columns. Chapters IV. to VII. treat respectively of blades, rotors, governing and bearings, containing, to a greater or less degree, valuable information. However, although the author states in his preface that he has attempted to produce a book "which shall not be so deeply involved in mathematics as to be above the intelligence of the practical engineer," it is the opinion of the reviewer that a great many of the engineers in question will shake their heads when they have looked at the chapter treating of rotors or at the chapter or gyroscopic action. In order to master these two chapters a person must be pretty familiar with integral calculus, and it would also seem that the author, in order to be brief, has left out steps in the mathematical development, thereby making the understanding more difficult than was necessary. The chapter on condensers is one of the best in the book; it contains a valuable discussion of the merits of the various kinds of condensers, and also rules for determining the best vacuum for each individual case.

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Chapter XI. treats of "Steam Turbine Performances." Compared with the treatment received in Stevens and Hobart's book the information furnished here is of small importance; but remembering the object of the book it is perhaps nearly sufficient. The next chapter has for its subject "Marine Turbines." The illustrations furnished are meager, and it is surprising to find that the longest part of the chapter is filled with a discussion of the ship propeller, of the turbo-air compressor and of the gas turbine. In the chapter on "Diagrams and Calculations" there is an agglomeration of various things, the two most important and useful parts being the numerical computation of both a reaction and an impulse turbine. The author points out in the preface that the book contains "two new heat diagrams —one for steam and one for gases—which will be found very useful in turbine design." It is the opinion of the reviewer that the modified temperature-entropy diagram of Mollier is more useful, especially as the large-sized Mollier diagram —as, for instance, contained in Stodola's book—can be used directly, and there is no construction of the diagram necessary, such as is the case with Mr. Foster's diagram. In Chapter XIV. some details of construction are considered, and the book closes with a short and rather unsatisfactory history of the steam turbine.

The book is presented in good form, although it cannot be compared in this respect with that of Stevens and Hobart. Because of the unusual excellence of the latter book it is perhaps unfortunate that these two books had to be reviewed at the same time, as necessarily a comparison could not be avoided.

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WATER-SUPPLY AND IRRIGATION PAPERS, U. S. GEOLOGICAL SURVEY.—Charles D. Walcott, Director. Washington, D. C.: Pub. Doc. Paper; 5¾ × 9 ins.

No. 161: Quality of Water in the Upper Ohio River Basin and at Erie, Pa. By Samuel James Lewis. Pp. 114; six plates and three text figures.

No. 179: Prevention of Stream Pollution by Distillery Refuse. Based on Investigations at Lynchburg, Ohio. By Herman Stabler. Pp. 34; one plate and five text figures.

The general plan of Mr. Lewis' paper is to follow up the various tributaries of the Ohio River and take up in succession the villages and cities on their banks, the typhoid statistics for those cities, and the character of their water supply and sewage disposal. Some towns on the Ohio below Pittsburg are considered in like manner, and about four pages are devoted to the water supply, sewage disposal and typhoid statistics of Erie, Pa. Chemical and bacterial analyses of water samples taken at or near some of the municipalities discussed are given, many of the analyses being "field assays." The paper as a whole affords a striking illustration of the sanitary backwardness of a large number of cities and towns in the section indicated. Notwithstanding generally sewage-polluted water supplies accompanied by high typhoid mortality rates, comparatively little has yet been undertaken in the way of thorough water purification. The case would doubtless be much worse for many of the communities if the typhoid statistics included all the instances of sickness and death from that disease. Although perhaps beyond the scope of this paper, a service would have been done had there been at least a brief discussion of the incompleteness of the typhoid statistics and the necessity or desirability of taking into account diarrheal diseases in attempting to study the relation between polluted water supplies and typhoid fever.

Mr. Stabler's paper (No. 179) is unique both because of its subject and because it presents a more or less theoretical and laboratory discussion of the trades waste disposal problem, followed by a brief account of a plant, along the same lines as the laboratory experiments, actually adopted to treat distillery wastes. The experiments and the working plant both involve the treatment of these wastes by evaporation, thus recovering very considerable amounts of cattle feed. The particular distillery in question has as its principal products rye and Bourbon whiskies, made from rye and corn, respectively.

## Text-Book of Engineering.

Reviewed by Arthur N. Talbot.*

A TEXTBOOK OF ENGINEERING.—For Secondary Technical Schools. By William R. King, U. S. N., Retired, Principal and Head of Department of Engineering, Baltimore Polytechnic Institute. Baltimore, Md.: The Friedenwald Co. Cloth; 6 × 9¼ ins.; pp. 408; illustrated. $4.

This book attempts to cover a wide field. Part I., The Elements of Steam Engineering, contains 202 pages and is divided into 15 chapters. It comprises such subjects as fuels and combustion, valve motion, the indicator, stage expansion engines, engine design, steam boilers, and the steam turbine. Part II., Transmission of Power by Belts and Gear Wheels, contains 25 pages on belting and wheels in train. Part III., Materials of Engineering, contains 35 pages on materials and testing materials. Part IV., The Elements of the Mechanics of Materials, contains 78 pages on shear, bending moment, beams, columns, shafts, and resilience. Part V., Elements of Graphic Statics, contains 38 pages on graphic statics and its application to trusses. The appendix takes up the units of force and mass and the distribution of steam by the slide valve. There is an index of 14 pages.

There may be difference of opinion as to whether it is fit to gather together in one book subjects of such diverse character as are here treated (fragmentary as they must be), and even whether it is best to give students of secondary technical schools matter in the form presented in this book. Naturally much of it is of a popular nature, but some of it is quite technical and mathematical. It can hardly be expected that students of secondary schools should learn much of the theory of the steam turbine, and yet it strikes one as strange that more is not given about the steam boiler. The chapter on engine design discusses cylinder sizes and ratios, piston speed, and crank velocity, but it does not attempt to treat proportioning of parts. The Materials of Engineering is a fairly good presentation. The Elements of the Mechanics of Materials covers most of the ground needed. Graphic Statics treats framed structures only. In all, the book strikes the reader as a collection of heterogeneous and unrelated matter rather than a harmonious and systematic whole. Simple matters and complex subjects are thrown together in an unexpected way. The reviewer cannot think that the selection and arrangement of topics is a wise one for the class of students the book is written for.

The book is generally well written and its field embraces important parts of engineering. The subject matter is presented in a manner which should be attractive to the student. In some cases the form of expression and the methods of treatment do not agree with practice in engineering schools, as when moment is defined as the *power* of the force to turn the body about a point, but on the whole the book is free from such defects.

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MONOLITAET DER BETONBAUTEN.—By N. A. Shitkewitsch, Professor in the Royal Engineering School at St. Petersburg. Berlin, Germany: Wilhelm Ernst & Son. Paper; 7½ × 10½ ins.; pp. 116; 60 illustrations in the text. 5 marks; American price, $2.

To reach working conclusions on the subject of monolithic construction in concrete, the author considers the various factors in separate chapters: Influence of Moisture, External Temperature, Internal Actions During Set, Strength and Elasticity of Concrete, Influence of Method of Execution, and finally Moisture and Frost. The use of steel reinforcement for preventing cracks is not discussed. Among the concluding recommendations we note with interest: The top surface of each layer of concrete should be roughened or loosened before depositing the next layer, in order to avoid horizontal cracks; In any concrete construction parts subject to different conditions should be made independently by notching to produce definite planes of weakness; To protect exposed concrete from atmospheric disintegration a surface protection of resistant material and of waterproofing are essential. It must be said, however, that many parts of the discussion are deficient in the thoroughness of theoretical and experimental deduction, and therefore are not as convincing as a monograph should be.

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BETON-KALENDER, 1907.—Pocket-book for Concrete and Reinforced Concrete Construction, and Related Branches. Published by "Beton und Eisen," with the co-operation of prominent experts. Second issue. In two parts. Berlin, Germany: Wilhelm Ernst & Son. First part, cloth; second part, paper; 4 × 6½ ins.; pp. 296 + 426; many illustrations. 4 marks; American price, $1.60.

This novel handbook of concrete working, brought out for the first time in 1906, is now in its second issue (it is to be published annually, as a yearbook). The 1906 issue was reviewed in these columns Jan. 18, 1906. Considerable improvement is evident in the 1906 Kalender. The novel plan was adopted of having many of the chapters revised by others than the original writers (with the consent of the latter) in order to secure the benefit of a fresh view of the subject under revision. A new thing, also, in the 1907 issue is the division of the work into two volumes, the first containing mainly tabular matter and data, while the second contains monographs on various branches of concrete lore.

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CONCRETE FACTORIES.—Cement Age, Vol. III., No. 5, October, 1906. Edited by Robert W. Lesley, Assoc. Am. Soc. C. E. New York: Bruce & Banning (1 Madison Ave.). Paper; 6¾ × 10 ins.; pp. 277 to 388; illustrated. 10 cts.; per year, $1.

About 75 pages of this number of "Cement Age" are devoted to brief popular descriptions of a number of reinforced concrete and concrete-block factories, warehouses, and the like, followed by descriptions of the principal types of reinforced concrete construction, and by the opinions of a number of architects and engineers on the value of concrete as a structural material.

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CONCRETE COUNTRY RESIDENCES.—New York: The Atlas Portland Cement Co. Stiff paper; 9¾ × 12¾ ins.; pp. 94; illustrated. $1.

There is embodied here a large collection of very handsomely reproduced photographs of country residences and other buildings of stucco on wire lath and on brick, and of reinforced concrete. A considerable proportion of the buildings illustrated, but by no means all of them, are as creditable as the half-tone work. The collection of views is interesting and valuable as showing what can be done, and in some instances what should be avoided, with the building materials named.

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## Electrical Books.

Reviewed by Henry H. Norris.*

A GRAPHICAL TREATMENT OF THE INDUCTION MOTOR.—By Alexander Heyland. Translated from the Second Edition by G. H. Rowe and R. E. Hellmund. New York: McGraw Publishing Co. Cloth; 5½ × 8¼ ins.; pp. 48; 28 illustrations in the text. $1. net.

THE ELEMENTS OF ELECTRICAL ENGINEERING.—A Text-Book for Technical Schools and Colleges. By William Suddards Franklin, Professor of Physics in Lehigh University, and William Esty, Professor of Electrical Engineering in Lehigh University. Vol. I. Direct Current Machines, Electric Distribution and Lighting. New York: The Macmillan Co. London, England: Macmillan & Co., Ltd. Cloth; 5½ × 8¾ ins.; pp. 517; numerous text illustrations and one folding table. $4.50.

This little volume gives in a very convenient form for study and reference the theory and practice of the well-known and standard Heyland method of testing and predicting the performance of an induction motor. The method involved but two simple tests, one of the pressure, current and power with the motor running light, i. e., without load, the other of the same quantities with the secondary winding short-circuited and the rotor or moving member blocked. The data resulting from these tests are applied to a system of vector, "circle" diagrams which permit the calculation of the performance of the motor under all conditions of load. The convenience of this method has long been appreciated by all persons who have to do with the testing of induction motors. Preceding the description of the Heyland diagram is a clear statement of the theory of the induction motor, and following the description are several practical examples worked out in full. As the title indicates the treatment is entirely graphical, permitting its use by those not familiar with the more involved theory. Hence a practical operator of average intelligence should be able to apply this method in practice.

The induction motor is rapidly coming into use for all kinds of shop and factory uses. On account of the recent expiration of the Tesla patents, competition in the marketing of the motors is becoming keener and prices are greatly reduced. We may, therefore, in the near future expect to see an increased appreciation of the induction motor, and any publication which tends toward this end will be heartily welcomed.

As the name indicates, Franklin and Esty's work is intended to form an introduction to the study of Electrical Engineering, and it approaches the subject from the practical rather than the theoretical side. The first or introductory chapter is of a theoretical nature, comprising a resumé of the elements of electric and magnetic circuits treated from the standpoint of the physicist. This chapter is not necessary to the treatment, being apparently intended as a review of the student's knowledge of electrical physics. The plan of the work involves a study of the direct current machines and devices before taking up those employing alternating current. This is what might be called the historical method, as contrasted with one beginning with the simpler alternating current apparatus. The proper method of approach for any student or general reader depends upon the nature of his previous experience. One who has seen and handled direct current apparatus exclusively will naturally make a better beginning in accordance with the plan of this book. On the other hand, it would seem more natural to take up the alternator, transformer, and other such simple apparatus before the complicated direct current machines if the student knows from personal experience what these are like. In view of these facts, it is the evident opinion of the authors that direct current devices are more familiar than the others to the student and general reader.

A book to be satisfactory for recitation use must contain in condensed form the elements of the subject with just enough of detail to illustrate the principles involved. The material must be arranged in sections and paragraphs for convenient reference, and each paragraph must lead logically from the preceding and teach a definite lesson. Judged from this standpoint the volume appears to be arranged in excellent form. A book arranged in this manner also makes excellent reading for the general practical engineer, assuming, as is true in the present case, that the treatment is not too theoretical. By means of supplementary references, practical test and general observations the knowledge gained from the text-book may be extended to any desired extent. Without some such practical experience neither this nor any other book will give satisfactory results in engineering work.

Aside from the introduction the text treats largely of practical topics. By a convenient arrangement of large and small type the essential practical parts are set off from the more theoretical matter. A number of appendices contain more advanced discussions of certain subjects which are considered important for the student intending to enter the profession of electrical engineering. An appendix, also, contains a large number of practical illustrative problems which should be solved by the reader if he wishes to obtain the maximum value from the study. A large part of the main body of the book is devoted to the electric generator and electric motor, which are clearly and practically described. The operation, testing and rating of these machines are given due attention, and economic conditions are not neglected. The applications of the various types of machines are briefly indicated, and incidentally the reader becomes familiar with the auxiliary devices necessary in successfully applying them to meet the demands of practice. A chapter each is devoted to storage batteries, electric current, distribution and electric lighting, giving in compact form and readable style the elements of each subject. In the appendices are more exhaustive treatments of electro-magnetism, characteristic curves and armature windings.

A book of this kind will do much to whet the appetite of the student for a more intimate knowledge of the subject. Such is the purpose of the text-book, which differs from the reference book in that it is not a compendium of information, but contains merely suggestions intended to stimulate mental activity.

OUTLINES OF PRACTICAL SANITATION.—For Students, Physicians and Sanitarians. By Dr. Harvey B. Bashore, Inspector for Pennsylvania Department of Health. Author of "Outlines of Rural Hygiene" and "The Sanitation of a Country House." New York: John Wiley & Sons. London, England: Chapman & Hall, Ltd. Cloth; 4¾ × 7½ ins.; pp. 208; 42 illustrations in the text. $1.25 net.

Within the limits indicated by its sub-title, this is one of the best and most practical books on sanitation that has ever come to our attention. Some of the most important of the topics covered are: habitations; water, milk and food supplies; the collection and disposal of waste; school and car sanitation; and vital statistics. There is a chapter on communicable diseases, one on personal hygiene, and one each on municipal sanitation and rural and suburban sanitation. The chapter on municipal sanitation has very little to do with engineering topics.

The chief criticism to be noted is that the author's ideas on sewage treatment seem confused, particularly as regards the relations of aerobic and anaerobic bacteria to intermittent filtration and to the septic tank. Exception may also be taken to the following sentence: "Diphtheria is a common disease in houses with wet foundations; easily explained by the experimental fact that diphtheria germs live for a long time on the walls of a damp cellar." Even supposing that it had been proved experimentally or otherwise that diphtheria germs lived for a long time on damp cellar walls, the question is, how would they get from that position to the throats of human beings? Perhaps it is surprising that in attempting to cover so wide a range of subjects in a popular manner, more slips and questionable statements were not made.

The book deserves a wide reading by not only "students, physicians and sanitarians," but also by the general public.

MANUAL OF WIRELESS TELEGRAPHY.—By A. Frederick Collins. New York: John Wiley & Sons. London, England: Chapman & Hall, Ltd. Cloth; 4¾ × 7½ ins.; pp. 232; 91 illustrations, mostly in the text. Cloth, $1.50 net; morocco, $2.00 net.

About a year ago Mr. Collins brought out a book on the history, theory and practice of wireless telegraphy, which was reviewed in Engineering News of Sept. 14, 1905. The present volume differs from the former one in being written particularly for wireless telegraph operators. Instructions and diagrams are given for wiring the various types of sending and receiving apparatus now used, for adjusting the instruments, tuning and syntonizing the circuits, and testing the devices employed. Instructions are also given regarding the management of ship and shore stations.

WIRING A HOUSE.—By Herbert Pratt. Being No. 6 of a Series of Practical Papers. New York: The Derry-Collard Co. Paper; 5½ × 8 ins.; pp. 21; six illustrations in the text. 25 cts.

This pamphlet contains very little information of interest to any one except a novice. The cases of open and concealed wiring are taken up with respect to a house in which there are to be 15 lights on the first floor and in the cellar, 7 lights on the second floor and 4 on the third floor. The necessary formulas and wiring table are given for calculating the correct size of conductors, but nothing is said regarding the proper placing of the lamps to secure the best illumination. This latter feature is one that should not be overlooked in wiring, even by a novice, and its introduction would have added largely to the practical value of the "Paper."

*Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.


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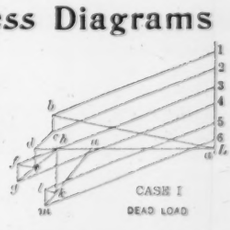


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## An Advanced Study of Reinforced Concrete.

Reviewed by Leon S. Moisseiff,* Assoc. M. Am. Soc. C. E.

ETUDE EXPERIMENTALE DU CIMENT ARME.—By R. Feret, Director of the Laboratoire des Ponts et Chaussées at Boulogne-sur-Mer. In "Encyclopédie Industrielle," begun by M.-C. Lechalas. Paris, France: Gauthier-Villars. Paper; 6½ × 10 ins.; pp. 777; 197 illustrations in the text, and many tables. 20 francs; American price, $6.

The quality and importance of M. Feret's work of research on cement, sand and concrete, has been known for many years to the civil engineering profession the world over, and when it was announced, some time ago, that a book on reinforced concrete by him was in preparation, its publication was awaited with the expectation that a distinct addition to the literature of the subject would be produced. This expectation has been fulfilled by the voluminous work now under consideration.

M. Feret calls his book "an experimental study of reinforced concrete." It well deserves the name, for it is a most thorough study of reinforced concrete, made by a practical experimenter and able theoretician. It is in no wise a text-book, with ready-made formulas and numerous illustrations of reinforced concrete construction in its many and varied applications. Rather, it treats of the material concrete and its combination with metal, and not of the applications of reinforced concrete. The author correctly assumes that what is of importance at the present time is the thorough knowledge of the material and its behavior under stress, and that this once gained the scientific application of the material in engineering structures will be a matter of course.

The book is divided into four parts, loosely connected with each other. The first part treats of experimental data, the second of theory and methods of computation, the third is a bibliography of reinforced concrete, and the last contains the author's researches on the resistance of mortar and concrete. In fact, each part is independent of the other and could just as well have been published separately.

The part covering the experimental data on reinforced concrete comprises 90 pages, and deals exclusively with experiments and tests made by the author. These tests were begun in 1893, and have been continued to date, and the author regrets that the earlier ones were not tested by the more elaborate and precise methods introduced since. Small prisms as well as full-sized beams were tested in bending. Altogether about two dozen beams, varying from 7 to 21 ft. in length, were tested. The effects of various bonds, the number of the bars, their thickness and position, the effects of the age and composition of the mortar were investigated and interesting results were obtained. A separate chapter is devoted to tests on small prisms and full-sized beams under alternating loads, and special attention is given to the variation in the elasticity of the mortar. The deformations at the various stages of the loading and unloading were carefully observed, and the author concludes that the assumption of perfect elasticity does not seem to apply to reinforced concrete beams, even after they have sustained a great number of reloadings. He further states that from the deformations of beams loaded with a steadily increasing load, as is usual for acceptance tests, only false conclusions can be drawn. Much valuable matter is contained in the record of the author's tests and they deserve careful study.

The second part of the book, comprising some 230 pages, is devoted to theory and computations. The author does not intend to add to the many practical formulas now in use, but he attempts to state the case theoretically as perfectly as possible, considering the several factors entering into an exact theory. Of course, great exactness is neither necessary nor desirable in practical work, but the simplified formulas used by designers should be based on definite knowledge, and the degree of their approximation must be known.

To establish a correct theory of reinforced concrete the author goes back to the first data of the theory of elasticity of solids. He analyzes first the action of a particle under stress and finds that if the laws of the relation of the elongation of the two component materials to their stress were known it would be possible to compute exactly the longitudinal stresses at any point of any plane section. The author examines the several kinds of rupture and their direct causes. He then proceeds to simplify the formulas established for the general case of a particle by several simplifying assumptions. The discussion of the various theories of the curve approximating the deformation curve of the concrete leads the author to the attempt "to free ourselves from the tyranny of these formulas and to build up on the curve itself as obtained directly by observation."

With the aid of the introduction of the "reduced bending moment" or the bending moment per cubic unit, the author develops a graphic method which enables him to determine the stress at any point of a beam at any stage of its elastic condition. M. Feret displays in this part of the book considerable mathematical skill, and it requires more study than could be given to it in the course of a review to fully evaluate the theoretical treatment.

More than a third of the book is devoted to the author's researches on the resistances of mortar and concrete to all kinds of forces, applied with a continuously increasing intensity or repeated a great number of times, with or without impact. Much attention is given to the adhesion of the constituent materials to each other, a field which has heretofore not been worked as fully as it deserves. Again the problem of repeated stress receives much attention, the author giving a number of tests of concrete blocks in compression under repeated loads. Among other conclusions the author finds that a beam not reinforced in its compressive part and subjected to alternate loading should not be stressed to exceed one-half or one-third of its resistance under a first load. Designers of reinforced concrete structures may well remember this.

The adhesion of mortar and concrete to other materials is studied most exhaustively, and all possible effects are considered, such as the influence of the mortar, the cement, the coarseness, grain and cleanliness of the sand, the proportions of the concrete, the nature and amount of water used in mixing, the character of the stone, its surfaces and porosity. The author succeeds in producing the most important monograph on the subject and it may well be predicted that it will exert a far-reaching influence on the subject of reinforcing concrete.

The part of the book containing the bibliography of reinforced concrete comprises some 140 pages. It is divided into five parts, under the following titles: General, Observations and Tests, Theory and Computations, Systems of Construction and Applications. It is the fullest bibliography on the subject ever published, and will be of great help to anyone interested in reinforced concrete. The author deserves the thanks of the profession for the great labor involved in the compilation of the data.

From the review of M. Feret's work it will be seen that it is not a text-book for ready use, nor a compilation of useful information on the subject, but an original contribution to the science of engineering. It is one of those works from which text-books are made. The student of reinforced concrete will find much valuable information and the experimenter many a good hint in the study of the work.

*Park Row Building, New York.

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FIVE FIGURE LOGARITHMS.—Of Numbers and Angular Functions, for the Use of the Engineer, Constructor and Student. By Henry Harrison Suplee. Philadelpnia, Pa.: J. B. Lippincott Co. Flexible leather; 4¼ × 7 ins.; pp. 91. $2, net.

Handy in size, and of excellent typography, this collection of logarithmic tables will be found a useful aid in ordinary calculation, that is, where five-place logarithms suffice. The common logarithms of numbers are given for every number to 10,000. Logarithms of trigonometric (circular) functions follow, for every minute from 0° to 45°. A table of hyperbolic (natural) logarithms of numbers, seven-place, for every 0.01 from 1.00 to 10.00 and every unit from 11 to 134, completes the book.

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RAILROAD ACCIDENTS.—Their Cause and Prevention. By R. C. Richards. Published by The Association of Railway Claim Agents (C. L. Young, Secy., C. & N. W. Ry., Chicago, Ill.). Cloth; 4¾ × 7¼ ins.; pp. 111. $1.

A general discussion of various classes of accidents is accompanied by citations of examples showing how the very accidents in question had happened to individuals. References to operating rules—which rules, if followed, would have prevented the accidents in many instances—are freely made throughout the book, and the rules themselves are given in an appendix forming the last 15 pages of the book.

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PROBLEMS IN SURVEYING, RAILROAD SURVEYING AND GEODESY.—With an Appendix on the Adjustments of the Engineer's Transit and Level. By Howard Chapin Ives, Assistant Professor of Civil Engineering, University of Pennsylvania, and Harold Ezra Hilts, Instructor in Civil Engineering, University of Pennsylvania. New York: John Wiley & Sons. London, England: Chapman & Hall, Ltd. Morocco; 4¼ × 7 ins.; pp. 136; illustrated. $1.50.

A laboratory manual, being designed primarily to facilitate the work of instructor and student, is likely to be caught on one horn or the other of a dilemma. It may be too closely adapted to the immediate needs of the instruction which called it forth, in which case it is apt to be narrow, leading to mechanical teachings and mechanical learning, and of no use at all to the man out of school, who, after all, is a student and needs books for instruction and review; or it may be so broad, making so much concession to other needs, that it trenches on the field of other and better books. One good way out of the difficulty is to neglect the narrowing demands of the work of class instruction, and make the book broadly a manual of procedure—a treatise containing little or nothing of either description or theory, but confining itself to the methods and routine of application. Such a book, written in a broad, well-informed manner, may be equally useful to the school student and to the man out of school.

It seems as though the writers of the book under review had had this expedient in prospect. They have called their work on the outer cover "Manual of Field Engineering," while on the title page a quite different name appears: "Problems in Surveying, Railroad Surveying and Geodesy." On reading through the book it appears that the title page description is the more appropriate.

The book comprises about 50 specific problems or tasks in surveying and the adjustment of instruments, in the separate fields of chaining, leveling, compass work, transit surveying, stadia surveying, the use of barometer, sextant, planimeter and other minor instruments, railroad surveying, geodetic work (baseline, triangulation and precise-leveling), and field astronomy. Each task is treated in concise manner on a uniform plan: the task is set, the size of party stated, the instrument equipment listed, a few remarks given on the theory governing the problem, the method of execution described, the necessary computations explained, and finally a form of notes prescribed. The half hundred problems are followed by an Appendix describing the adjustments of transit and level, and a set of seven tables.

It is, of course, quite out of the question in fifty problems to cover the range of surveying field-work comprehensively. The most that can be done is to select representative problems. In the present case they seem to have been selected with a view primarily to covering the various instruments and their principal methods of use. In consequence, some important special fields of field engineering, as railroad surveying, are given in a manner wholly inadequate for the purposes of the engineer, while mine surveying, for example, is not given at all. Even if it were possible, however, to cover all problems of surveying, it would probably not be practicable to give the several alternative methods of procedure in each. On this account it should be important to mention alternative methods, giving references for their full discussion. This the authors have omitted to do, doubtless merely in a striving after conciseness and simplicity.

The preceding should serve to indicate the scope and limitations of the work under review. As to the details of the treatment, it is excellent in clearness and systematic arrangement, qualities which are of first importance for such a book as this. In one or two short sections, as "Testing a Telescope," we think the authors have gone somewhat beyond their proper range; this section at least strikes us as being neither very valuable nor very clear, and we doubt the statement that spherical aberration is "corrected by making the object-glass of two different materials, flint and crown glass, which have different refractive and dispersive powers." But only minor passages are affected by this criticism.


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**PART I: General Review of the Subject.**—This has been added to and revised on the latest information as regards practical and experimental knowledge.

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**PART VII: Some Structures which have been Erected in Reinforced Concrete.**—This part has been brought up-to-date, and includes interesting examples of the latest designs.

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The first edition of this book appeared in 1892. Since then two complete revisions have been made, of which the last, represented by the present volume, shows by far the more radical changes. The object of the book remains the same as before: to give simple directions for the practical use and management of dynamos and motors.

Owing to the rapid progress of electrical engineering within the past few years, much of the matter in the previous edition became obsolete and has been eliminated. This is particularly true of constant-current motors, and is also true of constant-current generators, although to a lesser degree. As many of the latter machines are still in use, and possibly may become of renewed importance in connection with flaming arc lamps, the authors did well to retain a portion of the matter relating to them in the previous editions.

Among the new features of the book are: the matter on direct-connection of machines, that relating to the management of alternating current generators and motors of the single-phase and polyphase types, and that on the management of induction motors. Very little, if any, additional matter, however, is given regarding the common forms of electrical measuring instruments. One would naturally suppose that with the introduction of matter on the operation of alternating current machines in this edition, some mention would have been made of alternating current voltmeters and ammeters; in fact, it would not have been out of place to introduce a few simple rules on the care and handling of electrical measuring instruments by reason of their being so closely associated with the management of dynamos and motors.

## Publications Received.

ADVANCE CHAPTERS FROM MINERAL RESOURCES OF THE UNITED STATES, CALENDAR YEAR 1905.—David T. Day, Chief of Division of Mining and Mineral Resources. Washington, D. C.: Pub. Doc. Paper; 5¾ × 9 ins.

The Manufacture of Coke in 1905. By Edward W. Parker. Pp. 56; numerous tables.

Statistics of the Clay-Working Industries in the United States in 1905. By Jefferson Middleton. Pp. 62; numerous tables.

The Stone Industry in 1905. Prepared under the Direction of Edwin C. Eckel. Pp. 53; tables.

AN ANALYSIS OF GENERAL FLEXURE IN A STRAIGHT BAR OF UNIFORM CROSS-SECTION.—By L. J. Johnson, M. Am. Soc. C. E. [Harvard University, Cambridge, Mass.] (Reprinted from Transactions of the American Society of Civil Engineers, Vol. LVI., p. 169 [1906].) Paper; 6 × 9 ins.; pp. 169 to 196; one folding plate and ten text figures.

BEITRAG ZUR BESTIMMUNG DER FORMVERAENDERUNG GEKROEPFTER KURBELWELLEN. By Georg Duffing. Berlin, Germany: Julius Springer. Paper; 5½ × 8¾ ins.; pp. 46; 18 figures in the text and three folding plates. 1.6 marks; American price, 64 cts.

THE BUILDERS' UNIFORM SUB-CONTRACT.—A Form of Contract between Builders, Based upon the Requirements of the Uniform Contract Approved by the American Institute of Architects and the National Association of Builders. New York: E. G. Soltmann, 125 East 42d St. Paper; 8½ × 14 ins.; pp. 4. Sample copy for postage stamp; 10 copies, 25 cts.; 100 copies, $1.35.

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BULLETINS, GEOLOGICAL SURVEY OF OHIO.—Edward Orton, Jr., State Geologist. (Bulletins 4 and 5, Fourth Series, bound in one cover.) Washington, D. C.: Pub. Doc. Cloth; 6½ × 9¾ ins.

Bulletin 4: The Limestone Resources and the Lime Industry in Ohio. By Edward Orton, Jr., E. M., and Samuel Vernon Peppel, B. Sc. Pp. xv. + 365; 53 text illustrations and one map.

Bulletin 5: The Manufacture of Artificial Sand Stone or Sand-Lime Brick. By Samuel Vernon Peppel, B. Sc. Pp. 79; 10 illustrations in the text.

BULLETINS, ILLINOIS STATE GEOLOGICAL SURVEY.—Urbana, Ill.: Pub. Doc.

No. 1: The Geological Map of Illinois. By Stuart Weller. Cloth; 5½ × 8¾ ins.; pp. 26; large folding map.

No. 2: The Petroleum Industry of Southeastern Illinois. By W. S. Blatchley. Paper; 5¾ × 8¾ ins.; pp. 109; six plates and three text figures.

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